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ON THE ACOUSTIC EFFICIENCY OF FOG SIGNAL MACHINERY.*

BY

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SECTION I. HISTORICAL REVIEW OF FOG-SIGNAL EXPERIMENTS.

THE use of acoustic signals to warn fog-encompassed ships of dangerous localities or of impending collisions probably dates back to the very earliest days of navigation. As the range of the human voice in the open air is very limited, bells, gongs, or trumpets were employed in the earliest times to cover the distance required. With the invention of gunpowder, long-range signals were realized by firing off small cannon or mortars and such methods are, in some localities, still employed to the present day. In the leisurely days of sailing ships, likely to be entirely becalmed in foggy weather, the danger of collisions or of shipwreck was comparatively small. With the introduction of steam navigation and the development of keen competition for freight, the danger occasioned by taking the risk of navigating in foggy weather led to a heavy toll of lives and property through many disastrous shipwrecks. Speaking for the seaboard of Great Britain about the year 1875, Professor Tyndall states that during ten years at this period no less than 273 vessels were reported

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as totally lost in fog or thick weather.[1] He states, furthermore, that the loss was far greater on the American seaboard where fogs are more frequent.

It is not surprising, therefore, that the attention of various governments should have been directed to the study of improvement in the means of transmitting acoustic signals over long distances. Any attempt on my part to give even a partial account of the numerous tests which have been carried out on the subject of fog-signals would occupy the space of several complete lectures. I shall, therefore, be obliged to state very briefly the main results which have been arrived at by various investigators in order to present the outstanding difficulties in transmitting acoustic signals with the economy and certainty desirable in these important aids to navigation—difficulties which have by no means, as yet, been entirely overcome.

In the year 1873 the Trinity House of Great Britain set on foot trials with sound signals, following on a visit of a Committee of Elder Brethren to the United States the preceding year. A special committee was appointed to carry out these tests with the advice and assistance of Professor Tyndall, then scientific adviser to the corporation. An elaborate series of experiments was carried out at South Foreland, near Dover, the results of which formed the subject of a lengthy report. Tyndall's contributions were presented to the Royal Society of London, and his memoir on the subject was published in the Transactions for the year 1874.[2] The subject is dealt with at length in Tyndall's well-known work on "Sound," which has proved an invaluable guide and inspiration to so many workers on the subject of acoustics. In these tests the audibility of the signals was estimated entirely by ear. This is, of course, the most simple and practical method of carrying out the test, inasmuch as the experiment is carried out under the same conditions as when the

[1] Tyndall, "Sound," 3rd edition, Chapter vii. According to statistics compiled for the seaboard of Newfoundland by Mr. R. White, Inspector of Lighthouses, it appears that between the years 1820 and 1903 no less than 558 wrecks occurred in these waters, a large proportion, it is to be presumed, owing to fog. The positions in which ships have been lost to the year 1909 are shown on a "wreck chart" prepared by Mr. White and published by Messrs. Garland and Co., St. Johns, Newfoundland.

[2] Tyndall, "On the Atmosphere as a Vehicle of Sound," *Phil. Trans.*, vol. 164, 1874, pp. 183–244.

signals are heard by the navigator himself. As a method of comparing the relative merits of different types of fog-signal installations, this procedure leaves little to be desired, and information derived in this simple manner has been invaluable in the progress of fog-signal engineering. The results of this investigation are admirably summed up in a later Trinity House Report for 1901, to which I shall refer later, as follows:

"(1) The passage of sound through the atmosphere is not impeded by fog, or by falling snow, hail or rain;

(2) The most powerful sound-producing instrument then known was the siren as used in the United States;

(3) No sound signal should be relied on for being heard at a greater distance than two or three miles;

(4) Sound shadows may be formed by the intervention of points of land or the interference of the reflected sounds with the direct waves, whereby a signal may be rendered much less effective or quite inaudible in the area of such a sound shadow;

(5) An opposing wind seriously obstructs or diverts the passage of sound waves, while to leeward the sound travels to great distances without any serious interference;

(6) In an optically clear atmosphere the air may be rendered flocculent to sound by the existence of invisible acoustic clouds formed by air currents differently heated or differently saturated with vapor."

Meanwhile many observations and trials of the greatest importance relating to fog-signals were being made in the United States by the light-house engineers of that country. The experiments and reports of General Duane as well as those of Professor Joseph Henry were described and published in the Report of the Light-House Board for 1874.[3] For the most part, the experiences of the British and American experimenters was in general agreement, although the interpretation of many of the remarkable and unexpected phenomena observed formed for some time the subject of controversy between Henry and Tyndall. One of the most interesting features of this report is that, for the first time in the history of the subject, as far as I have been able to gather, an attempt was made by Professor Henry to employ a physical method of *measuring* sound intensity, as that distin-

[3] Reproduced in the "Scientific Writings of Joseph Henry," Smithsonian Institution, 1886, vol. i, pp. 370–510.

guished scientist evidently realized how unsatisfactory the ear was for the purpose. As early as 1867 he compared the action of a steam-siren, at Sandy Hook, with that of a Daboll trumpet, employing for the purpose a stretched membrane covered with sand placed at the small end of a conical tube which concentrated the sound-wave upon the membrane.

The results of fog-signal tests carried out in the United States to the year 1894 are published at length in Major Livermore's Report to the Light-House Board for that date.[4] I shall have time to mention only two points of this report which have a bearing on the main theme of my lecture this evening. In these tests, somewhat more elaborate means of measuring sound intensity than had hitherto been employed were devised by the scientific observers, Dr. White and Professor Hazen. In measuring the intensity of a signal, a standard scale of numbers was adopted in which zero denoted the absolute inaudibility of a signal and 100 its full power at a distance of 1000 yards with no intervening objects and under favorable conditions. The number 10 was chosen to denote the least sound of a signal which would be unmistakable supposing the observer to be unaware of the moment when it is to be expected. In order to standardize these estimates a sound-box was constructed of black walnut, $4 \times 3 \times 2$ inches, provided with a sliding cover and completely enclosed with thick felt. The sound was produced by means of a Jew's-harp fastened above a resonance cavity and sounded by an external lever. The sound proved to be so similar to that of a fog-alarm bell as to make the two difficult to distinguish when the intensity of the standard was adjusted to equality with that of the signal by sliding the cover or by removing the box to a suitable distance from the observer. It is evident that in this way a definite, though arbitrary, scale of intensity could be adopted and, if necessary, converted into an absolute scale by a laboratory measurement of intensity and quality. Although this was suggested at the time of the tests referred to, I have been unable to discover any record to indicate that this plan was ultimately carried out.

Another feature of Major Livermore's report to which I should like to refer here is the method there adopted of representing graphically the variation of sound intensity on the course of

[4] Livermore, "Report Upon Fog Signal Experiments," Appendix No. v to the Report of the Light-House Board, Washington, 1894.

the observing ship in the neighborhood of the fog-signal. The intensity of the signal according to the scale just described is indicated by the breadth of the line representing the track of the ship on a chart of the locality. In this way the capricious fluctuations of the strength of the signals under various conditions of wind and weather are indicated at a glance. In somewhat modified form I have adopted this method of representing the results of my own observations. (See Charts I, II and III.)

In the year 1901 an important series of tests was carried out by a special committee of the Trinity House under the scientific direction of Lord Rayleigh and Sir Thomas Matthews, Engineer in Chief.[5] The object of the trials was to discover the relative merits of various new types of fog-signal machinery. The experiments were carried out at St. Catherine's Point, Isle of Wight. Several members of the Committee always participated in estimating the strength of the signals by ear. Numbers on a scale ranging from 1 to 10 were assigned by the observers to represent the values of the sound heard. These were entered on special cards provided for the purpose and in comparing the relative merits of fog-signal apparatus the figures were averaged so that it was possible to say that siren *A* was 50 or 100 per cent. better than *B*. I am unable in the time at my disposal to give more than a passing reference to the most important results of these tests, which have, to a large extent, determined existing practice in Great Britain and Canada since that time. It was decided that in operating compressed air sirens little advantage in range of audibility accrued from raising the pressure above 25 pounds per square inch. For calm weather a low-pitched note (about 180 complete vibrations per second) was considered most suitable; when the wind was opposed to the course of the sound-waves or when the sea was rough and noisy, it was found that a high-pitched note penetrated further than a low-pitched one. The physical significance of these observations was discussed in a paper by Lord Rayleigh, published in the *Philosophical Magazine* for 1903.[6] It may occasion some surprise when I state that while a blast is being sounded from a siren which can be heard about

[5] "Report of Trinity House Fog Signal Committee on Experiments Conducted at St. Catherine's Point, Isle of Wight, 1901." (Darling and Sons, Ltd., London.)

[6] Rayleigh, "On the Production and Distribution of Sound," *Phil. Mag.*, vol. vi, 1903, pp. 289–305; "Scientific Papers," vol. v, pp. 126–141.

eight miles on a good day, energy is being expended at the rate of about 100 horse-power. While the high note of a Scottish signal tested at St. Catherine's was being sounded, the expenditure of as much as 600 horse-power was required. Lord Rayleigh raised the question as to whether these enormous powers are really utilized for the production of sound, or whether from some cause, possibly avoidable, a large proportion may not be wasted. By means of a simple mathematical calculation relating to the 7-inch disk siren tested at St. Catherine's, Lord Rayleigh concluded that the maximum pressure-change (estimated at 1/180 atmosphere) in the sound-wave produced was but an insignificant fraction of the operating pressure (25 pounds per square inch) and inferred that the conical trumpet acting as a resonating tube played an important part in utilizing the pressure of the compressed air. He also believed that a large proportion of the power applied to existing forms of sirens was not converted into sound, and that there was room for improvement in their construction with a view to reducing the very large demands made.

The experience of the French fog-signal engineers is summed up in a work published in 1908 on lighthouses and marine signals by Dr. C. Ribière, the Engineer-in-Chief, who has himself made many notable contributions to the subject.[1] As one would expect of the French scientific attitude of mind, serious and long-continued attempts were made to adapt some of the several known laboratory methods of measuring sound intensity in the hopes of elucidating some of the difficulties which I have just mentioned. Ribière states that attempts were made to record the motion of membranes vibrating under the influence of the signals; to measure the electric current generated by the vibrations of a telephone diaphragm; to record the signals on a phonograph-record, and to measure under a microscope the depth of the impression produced. Optical methods depending on the use of the interferometer to measure the change of refractive index in the atmosphere due to the passage of the sound-waves were also tried, as well as several other methods described in treatises and scientific journals. It was concluded that, while sound-intensity was capable of measurement under laboratory conditions, no means then existing could be employed successfully in engineering practice. For the most part

[1] Ribière, C., "Phares et Signaux Maritimes" (Encyclopédie Scientifique, Octave Doin et Fils, Paris, 1908).

the results of the French experiments agree with those of the British and American engineers except in a few points of technical detail which I shall not touch upon here, except by mentioning that a great deal of insistence is placed upon the desirability of obtaining further knowledge on the subject of the *acoustic efficiency* of fog-signal machinery. For the first time in the history of the subject, as far as I am aware, Ribière definitely suggests that sound-waves generated by a siren probably bear a close relationship to explosive waves whose mode of propagation has long been known to be very different from that represented by the classical theory of ordinary acoustics. Explosive waves have been studied experimentally in great detail by the ordinance department of the French artillery service. It is not surprising, therefore, that the part played by these abnormal phenomena in relation to fog-signal waves should have suggested itself to the French engineers. With this special aspect of the subject I shall deal in connection with my own observations.

SECTION 2. ON THE PRODUCTION OF SOUND BY THE NORTHEY DIAPHONE.

If I have taken up a considerable amount of time in presenting in a very summary fashion the experiments of previous investigators, it must not be inferred that I was familiar with the works of the authorities I have quoted at the time I planned the tests which I have the honor of describing this evening. If I had been in possession of more knowledge of the subject than the theoretical discussions I had read in Rayleigh's " Scientific Papers," which furnished the inspiration to undertake the work, it is hardly probable that I should have ventured into so complex and difficult a field of research. My experience in this connection certainly gives some support to the paradox occasionally heard in research laboratories, that a certain amount of healthy ignorance is the best incentive for undertaking some new line of work. At any rate, it so happened that I had just read Lord Rayleigh's papers on the subject of fog-signals when an opportunity offered itself in the summer of 1912 of accompanying the Director of the McGill Physics Building, Professor Howard T. Barnes, on a cruise to the Straits of Belle Isle, with the object of making a special scientific study of icebergs, which in the North Atlantic constitute a serious menace to the safety of navigation. Accommodation was

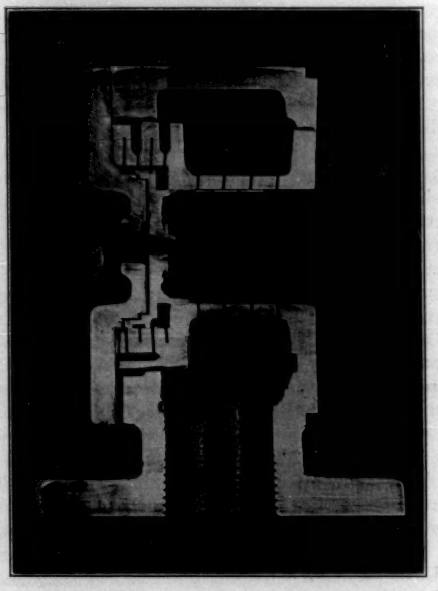
provided by the Canadian Government on the lighthouse tender "Montcalm" during one of her routine cruises to the Gulf of St. Lawrence. I had in this way very exceptional opportunities of studying the Canadian lighthouse and fog-signal system.

The type of fog-alarm which has found favor in Canadian waters and has been installed in many localities is a modified form of compressed air siren, of extremely elegant mechanical construction, an invention of Mr. J. P. Northey, of Toronto,[8] called by him a "diaphone." The essential feature of this apparatus consists of a hollow piston in which are cut a number of equidistant circular slits or ports whose planes are perpendicular to the axis. This piston fits closely in a cylinder in which are cut corresponding slits. These are alternately opened and closed by the vibratory movement of the piston. These oscillations are produced by means of a special driving head fitted with a valve-system somewhat resembling that of a compressed-air riveter. Air at a pressure of about 25 pounds per square inch is supplied from compressors and storage tanks to a chamber surrounding the exterior stationary cylinder. As the hollow piston vibrates, the intermittent puffs of air generated give rise to intense sound-waves which are propagated to the external atmosphere through a continuation of the outer cylinder in the form of a short conical trumpet tuned to resonance with the pitch of the signal note, about 180 complete vibrations per second. A most important characteristic of the diaphone is the fact that a very considerable variation of operating pressure has very little effect on the pitch of the signal note. This apparatus gives rise to an extremely powerful and well-sustained note whose quality as heard in the distance was, as far as I could judge, that of a very nearly pure tone. At the end of a blast, the slowing down of the piston gives rise to a short and powerful terminal note of diminishing pitch. This "grunt" (as it is designated at sea) is characteristic of the diaphone signal and is of great practical importance in navigation, not only in differentiating the note from that of ship-siren, but in

[8] For detailed descriptions of this apparatus, see Northey, J. P., United States Patents, No. 736,428, Aug. 18, 1903; No. 879,190, Feb. 18, 1908; No. 973,960, Oct. 25, 1910; No. 1,016,187, Jan. 30, 1912. The word *diaphone* is compounded of the two Greek words $\delta\iota\acute{\alpha}$ = *through* and $\phi\omega\nu\acute{\eta}$ = *voice* or *sound*.

enabling the direction of the signal to be estimated with fair accuracy. This peculiarity was entirely unexpected in the development of the diaphone and is emphasized in modern installations. The purity of the diaphone note, together with the fact that the auxiliary machinery was of such a character as to lend itself

FIG. 1.



Small model of Northey diaphone sectioned to show details of construction.

extremely well to the control and measurement of air pressure, flow and temperature, made it evident to me that here, *par excellence*, was the type of sound generator suited to a physical study of the mode of propagation of powerful fog-signal waves and of energy losses in the machine itself and in the atmosphere.

SECTION 3. ON THE NUMERICAL CHARACTERISTICS OF AERIAL SOUND-WAVES IN RELATION TO THE AUDIBILITY OF FOG SIGNALS.

At this point it is necessary for me to interrupt my narrative and present the main lines of theoretical reasoning which led me to plan the researches which I am about to describe. It is a matter of common knowledge that periodical pressure disturbances in the atmosphere may be set up by the vibrations of a bell struck by a hammer, by the rapid oscillations of a stretched string, or by the intermittent escape of puffs of air as in a siren. This pressure disturbance travels outwards in the form of a sound-wave with a velocity of about 1100 feet per second. Let us imagine a superhuman experimenter engaged in studying the effect of sound-waves on a supernaturally sensitive aneroid barometer. He would observe the indicating hand of his instrument fluctuate rhythmically, showing the existence of minute pressure-changes in the atmosphere. If he could follow in detail the motion of the hand of his instrument he would be *analyzing* the sound-wave. A perfectly regular backward and forward motion would correspond to a *pure tone;* an irregular movement, without rhythm, corresponds to a *noise*. Between the two he might observe an infinite variety of periodic types of motion corresponding to what are called *complex tones*. Associated with the pressure fluctuation in a sound-wave is a minute backward and forward motion of each particle of air—referred to as the *displacement*. While all these points are fully dealt with in all text-books on physics, it is somewhat curious that very few answer the question which an engineer would naturally ask, and which is of fundamental importance in fog-signal work—what is the magnitude of these pressure-fluctuations and displacements in a sound of given pitch which is of sufficient intensity, let us say, to be just audible to the normal ear? This question was first answered as long ago as 1870 by Boltzmann and Töpler,[9] and was independently dealt with by Lord Rayleigh in papers published in 1877 and 1894.[10]

[9] Töpler and Boltzmann, "Uber eine neue optische Methode die Schwingungen tonender Luftsäulen zu analysiren." *Ann. Phys. Chem.*, 1870, pp. 321–352.

[10] Rayleigh, "On the Amplitude of Sound Waves," *Proc. Roy. Soc.*, xxvi, 1877, pp. 248–249. "Scientific Papers," vol. i, p. 328. See also a paper "On the Amplitude of Aerial Waves which are but just Audible," *Phil. Mag.*, 28, 1894, pp. 365–370. "Scientific Papers," vol. iv, pp. 125–129. These experiments are briefly described in Rayleigh's "Theory of Sound," vol. ii, 1896, pp. 434–440.

I have set out in the accompanying table a few of the early estimates of the numerical characteristics of just audible sound-waves, quoted from the papers just referred to.

NUMERICAL CHARACTERISTICS OF JUST AUDIBLE SOUNDS.

(Wave-length of yellow light about 6×10^{-6} cm.)

Pitch	Pressure amplitude in atmospheres.	Displacement amplitude in centimetres.	Authority and Remarks.
181	9.2×10^{-8}	$.19 \times 10^{-6}$	Töpler and Boltzmann (1870). Measurement of density fluctuations in organ pipe measured by Jamin refractometer.
256	$6.0 \times 10^{8-}$	0.127×10^{-6}	Rayleigh (1894). Rate of decay of tuning fork fitted with resonator.

The extreme minuteness of the physical effect necessary to influence the ear will no doubt be a surprise to many. The authorities I have just quoted have also drawn attention to a most extraordinary result, not very generally known, and of the highest degree of interest.

Lord Rayleigh estimates that the stream of energy (*i.e.*, the amount of energy in the sound-waves crossing a unit area per second) from an ordinary candle affecting the eye at a distance of 3000 metres (*i.e.*, about 2 miles) is about equal to the stream of energy just audible to the ear. It appears from this that the amounts of energy required to just affect the eye and ear are roughly equal and extraordinarily small. The point should be carefully noted by inventors who propose to substitute auxiliary apparatus to aid the naked ear in detecting fog-signals at sea. The *intensity* of sound is conveniently measured by the flow of energy in the sound-waves crossing unit area in unit time and, in the case of pure tones, is proportional to the square of the displacement- or pressure-amplitude. We are told in text-books of physics that the intensity of sound from a source of disturbance falls off according to the inverse square law, as is the case with radiant energy. In the open air, under conditions met with at sea, the law is not even a rough approximation, as may be seen from an inspection of Charts I, II and III. However, at the time I first became interested in the Northey diaphone, in the summer

of 1912, I made a very simple calculation, which we are now in a position to follow. According to the results of Boltzmann and of Lord Rayleigh which I have just mentioned, we know the rate of flow of energy just audible to the unaided ear. If, now, a fog-signal generator is just audible on a favorable day at 10 miles (no very great distance for a modern type of apparatus such as that at Father Point), we are able to calculate the rate at which energy must be supplied at the diaphone, assuming that the inverse-square law holds. Making use of Boltzmann's data (referring to a note of the same pitch) we arrive at the surprising conclusion that the expenditure of energy at the resonator should be a little less than one-third of a horse-power. The diaphone we are considering gives two blasts of 3 seconds each per minute. In order to provide sufficient air, a 10-H.P. gasoline engine operates continuously, compressing air into the storage tanks to be all expended in one-tenth of the interval required to make good the air lost. It follows that, in terms of the engine-power supplied, energy is expended at the rate of 100 H.P. during a blast. We are told in the St. Catherine's report that when the high note of the Scotch siren was being sounded, energy was being spent at the rate of 616 H.P. In order to explain this somewhat extraordinary result we have first of all to settle two questions. First, are fog-signal waves propagated through the free atmosphere on a calm day without loss of energy, and is the inverse-square law true? Secondly, what are the losses of energy in the sound-generator itself, *i.e.*, what proportion of the available horse-power is converted into sound?

I decided, if facilities could be obtained, to undertake a series of tests to obtain some light on these two questions and forthwith took up the matter with Dr. H. T. Barnes, who not only placed the resources of the laboratory at my disposal for the work, but kindly offered to bring the importance of this field of research to the attention of the Canadian Government. As a result, very exceptional facilities for the work were provided by the Department of Marine and Fisheries.

It now became necessary to devise a method of attacking the two problems I have enunciated. Considering these in order, it was evident that the study of atmospheric and propagation losses would require some form of portable sound-measuring apparatus. Such an instrument I thought could be used with comparative ac-

curacy and ease owing to the remarkably smooth note of the Northey diaphone, to which I have already referred. I had not proceeded far in searching through all available papers on the subject of sound-measurement, when I came upon the work of Professor A. G. Webster of Clarke University to whom I addressed a request for a copy of a paper published in the year 1904[11] as a contribution to a volume of scientific papers dedicated to the late Professor Boltzmann. I not only received the paper referred to but an invitation to visit the laboratory of Clarke University and make myself familiar with the most recent developments of sound-measuring apparatus. Of this invitation I readily availed myself in July, 1913, with the result that Professor Webster not only offered to supervise the construction of a "phonometer" specially designed as to pitch and sensitiveness to measure the sound from the diaphone, but placed at my disposal the manuscript of a memoir dealing with the entire theoretical and experimental development of his sound-measuring instruments.

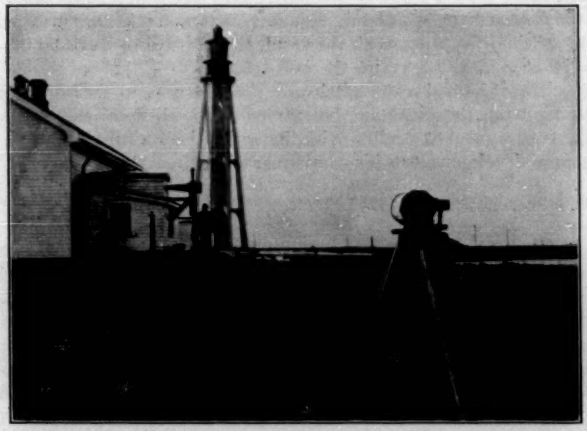
SECTION 4. ON THE MEASUREMENT OF SOUND BY MEANS OF THE WEBSTER PHONOMETER.

The Webster phonometer is, in fact, the practical realization of the ideal, supernatural aneroid barometer which I employed for the purposes of illustration a few moments ago to measure, in imagination, the minute pressure-fluctuations which occur in sound-waves of ordinary loudness. It consists, in brief, of a hollow cylindrical chamber (called a Helmholtz resonator from the first experimenter to study its acoustic properties), one end of which is pierced by a smooth hole communicating freely with the atmosphere. The other end also contains a circular opening over which is cemented a very uniform plate of the best mica obtainable (such as is employed in the construction of phonograph sound-boxes). The resonator is made up of two accurately turned, telescoping cylinders so that its volume may be altered at pleasure. It is a familiar fact that a hollow vessel emits when suitably excited a fundamental (*i.e.*, of lowest pitch possible) note of a certain frequency depending to a slight extent on its

[11] Webster, A. G., "On the Mechanical Efficiency of the Production of Sound," "Boltzmann Memorial Volume," pp. 866-875. (J. A. Barth, Leipzig, 1904.) A short description of the apparatus is given under the title "A Complete Apparatus for the Measurement of Sound," British Association Report, 1910, p. 534.

shape, but chiefly on its volume. It will also resound to and reinforce a note of the same pitch, a phenomenon referred to as *resonance*. By altering the volume of the resonator of the Webster phonometer it is possible, within certain limits, to "tune" the instrument to any desired frequency. When this adjustment is correctly made, the pressure fluctuations in the interior of the resonator are much reinforced, by an amount which may be ex-

FIG. 2.



Webster phonometer mounted on a theodolite tripod. Building to the left is the fog-signal station showing the trumpet of the diaphone. Father Point lighthouse in the background.

actly calculated. The mica diaphragm at the back of the resonator is thus caused to vibrate, and, if it is possible to measure the amplitude or range of motion of the diaphragm in inches or centimetres, Professor Webster has shown how to calculate in absolute measure the numerical characteristics of the sound-waves in the free atmosphere passing by his instrument. For sounds of ordinary intensity the amplitude of motion of the mica diaphragm is so small that it is necessary to make use of a special optical or interference method to measure it in terms of a wave-length of

light. This instrument, which may be called a "standard phonometer," corresponds to the standard electrical measuring instruments which are carefully kept in specially fitted laboratories. For every-day purposes a secondary standard is employed. In order to magnify the motion of the mica disk sufficiently to measure it easily, an ingenious mechanism has been devised by Professor Webster which satisfies conditions of portability and of use under practical conditions. The mica disk carries, firmly clamped at its centre, a sharp steel point. A narrow steel strip, suitably held taut at both extremities in a fork capable of adjustment in two directions at right angles by slow-motion screws, has its centre in contact with the steel pin in such a manner that a slight movement of the point causes it to twist through a small angle. In order to magnify the twist, the familiar galvanometer lamp and scale device is employed in miniature. Cemented to the steel strip is a minute concave mirror. The filament of a small flash-light tungsten lamp is mounted over a microscope eye-piece whose optical axis coincides with that of the phonometer. The straight narrow filament of the tungsten lamp is reflected and concentrated into a distinct image so as to appear sharply defined against a graduated scale in the microscope eye-piece. As soon as the mica disk is set into vibration by sound-waves passing near the resonator, the image of the filament is drawn out into a bright band with sharply defined edges. The width of the band is proportional to the amplitude of the sound-waves as measured by pressure-fluctuation or displacement. This secondary standard may be calibrated in terms of the absolute standard by simultaneous measurements by the two instruments of the note emitted by a standard "phone" (*i.e.*, a sound-generator especially designed to give a pure tone of known characteristics).

The "phone" or standard sound-generator, is merely the phonometer worked backwards: it is easily understood that if the diaphragm of the phonometer is made to oscillate through a known amplitude, it is possible to calculate the numerical characteristics of the spherical sound-waves emitted. By the use of the standard "phone" it is possible, by making use of an ordinary phonometer, to calculate the acoustic output of any sound-generator of the same pitch, such as a violin, a cornet, or even the human voice. For this purpose it is only necessary to have the two sources sounding alternately side by side and adjust the

amplitude of motion of the standard source until the same reading is obtained on the phonometer placed at a suitable distance. The amount of mechanical energy required to produce the notes on the musical instruments mentioned is easily measured, so that their *acoustic efficiency*, or ratio of energy input to acoustic output may be determined. Such determinations for ordinary musical instruments were first carried out by this method in 1902 and described in Professor Webster's 1904 paper just referred to. The results are extremely interesting. To quote a few of the determinations only, the acoustic efficiency of the violin comes out to be 0.00052 or about one part in two thousand. That of the cornet is in the neighborhood of 0.0011 or roughly twice as great, while the human voice comes out surprisingly well with an efficiency of 0.0095 or nearly one per cent. These results are summed up by Professor Webster in the graphical statement that it would require ten million cornets all sounded at once to emit a horse-power.

SECTION 5. ON AERIAL SOUND WAVES OF LARGE AMPLITUDE.

The methods just described for measuring the acoustic efficiency of sound-generators of small power depend for their validity on the mathematical theory of sound-waves in which the pressure-amplitude is an extremely small fraction of an atmosphere, at most a few parts in one or ten thousand. It occurred to me when I was planning these tests that it was very probable that the pressure amplitude at the narrowest part of the trumpet of the diaphone could easily amount to a very considerable fraction of an atmosphere, say a hundredth or a tenth. Now, it was pointed out as long ago as 1808 by the French mathematician, Poisson,[12] that in these circumstances the mathematical theory of the propagation of waves of large or finite amplitude was entirely different from that of ordinary sound-waves of very small amplitude. The physical significance of this result was first pointed out in 1848 by Sir George Stokes [13] who showed, without any mathematics at all, that in a plane wave of sound propagated in an ideal

[12] Poisson, "Mémoire sur le théorie du son," *Journ. de L'Ecole Polytechnique*, t. vii, 1808, p. 319.

[13] Stokes, "On a Difficulty in the Theory of Sound," *Phil. Mag.*, Nov., 1848; "Mathematical and Physical Papers," vol. ii, p. 51.

elastic fluid (*i.e.*, without viscosity or internal friction, and without thermal conductivity or the property of transferring heat from hot to cold parts of the medium), the parts of the wave where the density is greater will gain continually on those where it is less. Thus, after a certain lapse of time, a discontinuity will occur in a manner somewhat analogous to the way in which a water-wave will break when the accelerations of the water-particles become too great. It is possible to calculate for a plane wave transmitting a given amount of energy how far it will travel before this break will occur. In the case of waves of ordinary intensity and pitch, this distance is many hundreds of times greater than the dimensions of laboratories where such an effect could be observed. It is otherwise, however, when we come to deal with very intense waves, or ordinary waves of very high pitch when the distance referred to may amount to a few metres only. As to what happens when the theoretically calculated discontinuity sets in is still an unsolved problem, especially when dealing with diverging spherical waves. Of course, in reality, the viscosity and thermal conductivity of the air play an important part. This far more difficult problem has been dealt with by Lord Rayleigh [14] in a lengthy and complicated paper published in 1910. The theory is applied to explain the very curious and abnormal laws of air-resistance to projectiles moving with a velocity greater than that of sound.

If we turn from the attempts of theory to consult the verdict of experiment, which constitutes a court of high appeal to which we must ultimately have recourse, we find that it has long been known that very intense waves, such as those caused by the detonation of explosives, have a velocity distinctly greater than that of ordinary sound. This subject has been studied in great detail by M. Vieille,[15] Engineer-in-Chief of the French Ordnance Bureau (*Poudres et Saltpêtres*). In his memoir published in 1900 he showed that the velocity of the wave generated by the sudden rupture of a thin metal diaphragm under a pressure of 27 atmospheres is nearly double that of ordinary sound, while that

[14] Rayleigh, "Aerial Plane Waves of Finite Amplitude," *Roy. Soc. Proc.*, A, vol. 84, pp. 247–284, 1910; "Scientific Papers," vol. v, pp. 573–619.

[15] Vieille, "Etude sur le rôle des discontinuités dans les phénomenes de propagation," Mémorial des Poudres et Saltpêtres, t. x, pp. 177–260 (Gauthier-Villars, Paris, 1900).

of the waves generated by the detonation of modern high explosives attains as high as three times the normal value.

SECTION 6. ON THE THERMODYNAMIC MEASUREMENT OF ACOUSTIC EFFICIENCY.

It is thus evident that we must be prepared to meet with very abnormal conditions in studying the signals emitted by a diaphone, especially close to the oscillating piston, at which point I wished to measure the acoustic output. In this locality the sound-waves probably resemble intermittent explosive waves rather than the normal waves whose characteristics are easily measured by means of the phonometer. It was thus necessary to devise a method of efficiency measurement entirely independent of any acoustic theory, and for the purpose a thermodynamical method, generally applicable to any type of compressed-air machinery, was developed. The principle of the method may be easily understood by reference to a fact familiar to all engineers. It is well known that when a compressed-air drill is being operated at full load, the air which escapes through the exhaust pipe becomes so cold that hoar-frost gathers on its exterior, in spite of the warm surrounding atmosphere. If, however, the air be allowed to escape through the valves into the exhaust pipe without operating the drill, there is no perceptible fall in temperature. It is thus evident that by measuring the temperature difference of the air at the intake and exhaust we should obtain a measure of the rate at which the drill is doing mechanical work, making use of a few simple thermodynamical formulæ. In the application of this idea to measuring the acoustic output of the diaphone, a number of serious experimental difficulties had to be overcome. It was estimated beforehand that the temperature-difference would certainly not amount to more than a few degrees, so that some form of electrical resistance thermometer would have to be employed. If it had been possible to have the diaphone sounding a continuous blast, the test would have presented no serious difficulty. The capacity of the pumping engine was sufficient to furnish compressed air for a blast of six seconds per minute only, so that it was necessary to design a thermometer with so small a heat capacity that it would take up its final temperatures in that time. This was accomplished by making use of a very fine silk-insulated iron wire (1/1000 inch in diameter) wound in the form of a coil in spe-

cially designed frames, one of which could be inserted in a large valve on the compression side of the diaphone, and the other inserted in the trumpet about five inches from the vibrating piston. Each winding of the fine iron wire was supported at intervals by loops of silk cord so that no part of the winding was in contact with the solid frame-work. The heat capacity of the instrument was thus reduced to a minimum, that of the wire itself. By connecting the thermometer to a Wheatstone bridge and bridge-wire in the usual way, it was found possible to measure temperature-

FIG. 3.

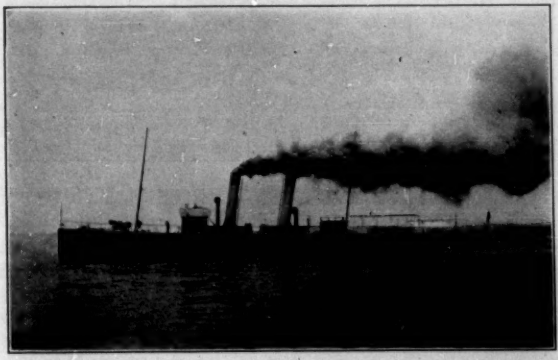
Apparatus for the thermal measurement of acoustic output of diaphone. The skeleton construction of the iron-wire resistance-thermometers is clearly shown.

differences to 1/100 of a degree C., making use of a portable Weston galvanometer to obtain a balance. A third difficulty which had to be provided for was the temperature rise in each thermometer, due to the frictional (or "kinetic") heating of the air rushing past the wires. Owing to the differential connection of the two instruments, the two effects would tend to counteract one another, but to get rid of the difficulty entirely it was planned to take observations in the following way. First, a temperature difference would be taken with the diaphone sounding a note at a given pressure. Then the diaphone piston would be blocked and

FIG. 4.

Acoustic survey carried out from a ship's boat. The phonometer is shown mounted at the bow of the boat. The results obtained are shown graphically in Chart I.

FIG. 5.



C. G. S. "Lady Evelyn." From this ship were taken the phonometer observations for the long range acoustic survey, the results of which are shown graphically in Charts II and III.

so adjusted that at the same pressure the rate of air-flow would be the same as when sounding. In this case, however, as no energy is converted into sound, and as the velocity of air past the ther-

mometer wires is the same, the frictional heating would be as before. By taking the difference of the differential thermometer readings, we are enabled to eliminate the kinetic heating and thus arrive at the true temperature fall due to the conversion of compressed-air energy into sound.

SECTION 7. ON THE FOG-SIGNAL EXPERIMENTS CARRIED OUT AT FATHER POINT, QUEBEC, SEPTEMBER, 1913.

I now pass on to the actual details of the experiments which I carried out on the Father Point fog-signal during the month of September, 1913. Through the courtesy of the Department of Marine and Fisheries, permission was given to operate the diaphone at will for the purpose of the tests. Through the kindness of the Postmaster General, I was authorized to take up permanent quarters on the mail tender, "Lady Evelyn," stationed at Rimouski, and to make use of this ship in carrying out acoustic surveys in the neighborhood of the Father Point signal, a few miles away. Mr. H. H. Hemming,[16] at the time one of our McGill students, assisted in the experiments and proved himself invaluable in taking observations. Our regular routine was to leave Rimouski wharf every available morning on the acoustic survey. The ship was skilfully navigated over a series of courses under the guidance of her commanding officer, Captain J. B. Pouliot. Weather conditions (velocity and direction of wind, description of sea and sky) and sextant observations to obtain the position of the ship at stated times over various parts of her course were left in the hands of Mr. Hemming; air-temperature was provided for by a self-registering thermometer; through the kindness of Dr. Barnes I was able to install one of his self-recording marine thermometers for obtaining sea-temperatures. I personally undertook the phonometer readings which were taken at the rate of one a minute. I may say that the phonometer from the start proved to be a complete success and that the great progress made in carrying out, under practical conditions, measurements of sound intensity must be attributed to this achievement of Professor Webster. The fog-signal itself had only to be started by the Father Point light-keeper to continue running without further attention, the pressure

[16] Now Lieut. H. H. Hemming of the Third Field Survey Company, in active service in France.

remaining remarkably constant. As I have already pointed out, small fluctuations of pressure are with very little effect on the pitch of the note emitted. This circumstance, together with the smoothness and purity of the tone of the Northey diaphone, contributed very materially to the success of the acoustic survey. The results have been plotted on a series of charts and diagrams, three of which are reproduced in Charts I, II, and III.

FIG. 6.

Taking phonometer observations from the C.[G. S. "Lady Evelyn" on a rainy day.

The acoustic surveys generally occupied the forenoon. About noon Mr. Hemming and I were put ashore at Father Point. Here we occupied ourselves in making preparations for the efficiency tests which were, after a few initial difficulties, duly carried out. The results obtained have enabled us for the first time to form some estimate of the amount of power delivered by a siren as sound. In the particular diaphone tested, operated under the best conditions, it was found that nearly two and a half horse-power (2.36 H.P. in one of the tests) may be so utilized.[17]

[17] This estimate will, of course, have to be verified by further tests by different methods before being accepted as final.

Observations were taken with the diaphone sounding at different pressures so that the corresponding variation of acoustic output could be studied. Pressures were accurately measured by means of a mercury gauge. By measuring the fall of the gauge during a six-second blast it was possible to calculate the total air-consumption, knowing the volume of the storage-tanks and the rate of compression of the engines. In rating the efficiency of the diaphone it is necessary to adopt a somewhat arbitrary standard of reference. Air compressed to a given pressure and consuming a given amount of air per second is capable of doing mechanical work at a rate depending on the type of compressed-air engine used. That taken as our standard was, for purposes of discussion, one operating on an adiabatic cycle and capable of converting (in some way as yet undiscovered) *all* the energy of compressed air into sound. Efficiency rated in this manner I have called the *over-all* efficiency. Several series of observations gave fairly concordant results for the acoustic outputs at different operating pressures. In each of the tests, the over-all efficiency attained its maximum value at an operating pressure in the neighborhood of 20 lbs. per square inch above atmospheric. In one instance the maximum was nearly 6 per cent.; in another, after some adjustments to valves admitting air to the diaphone, the maximum rose to a little over 8 per cent. Full details of these tests will be found in a detailed account of the work which will be published shortly.

SECTION 8. ON FUTURE PROBLEMS IN ACOUSTIC ENGINEERING.

I think that it will be generally conceded from the description of the new methods of sound measurement which I have described, that the subject is in a fair way to being dignified by the title "acoustic engineering." It is also evident that a great deal remains to be done in this field. Regarding a sound-generator as a mechanical means of converting some sort of motive energy into sound, it is apparent that an over-all efficiency of 6 to 8 per cent. (or probably twice as high in the newer types of diaphones) leaves considerable room for improvement, although these numbers are many times greater than those derived for small-powered musical instruments. At this stage the questions which remain to be solved by future work may be stated as follows:

(1) Is there any limit (as in the case of ordinary heat-engines) to the proportion of power capable of being converted into sound-energy?

(2) How much of the sound-energy, once delivered as such at the narrowest part of the siren-trumpet, is wasted owing to losses in the trumpet itself and in the atmosphere outside?

To answer the first question it is necessary to undertake the mathematical theory of an ideal siren taking into account the equations of propagation of sound-waves of finite amplitude. There is no difficulty in estimating, according to the classical theory, the characteristics of a plane sound-wave transmitting power at the same rate per unit area as in the diaphone sounding under best conditions. The results are as follows:

Pitch	175 complete vibrations per second.
Rate of transmission of power across 14 sq. in. (area of diaphone trumpet 5 inches from piston)	2.36 H.P.
Pressure amplitude	0.128 atmosphere.
Displacement amplitude	1.08 inches.
Maximum velocity of particle in sound-wave	99 feet per second.
Average velocity of air (calculated from rate of air consumption)	137 feet per second.

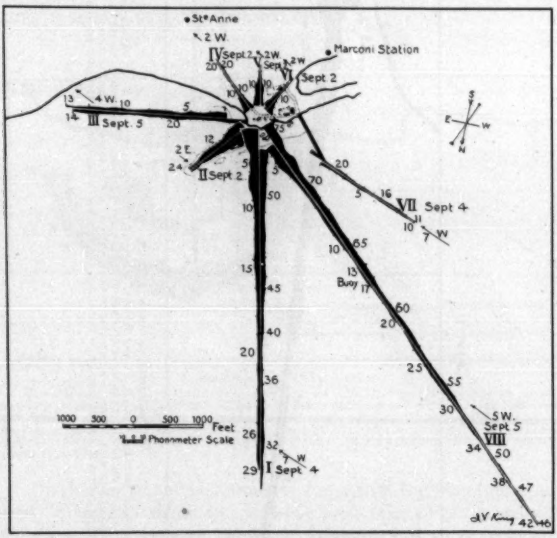
By an approximate solution of the exact equations of propagation, it may be estimated that a plane wave transmitting this amount of power unit area could travel only some distance between 9.7 and 10.7 feet before discontinuity sets in. In reality, this result will be modified by viscosity and thermal conduction, but the inclusion of these factors in the theory introduces unmanageable complications.

A little consideration enables us to understand how energy may be dissipated in a "finite wave," such as that we have just considered. Compressions and rarefactions of 1/10 atmosphere give rise to adiabatic heating and cooling of about 12° C. above and below the normal temperature. It has already been pointed out that there is a tendency for the compression to overtake the rarefied part of the wave so that ultimately these pressure inequalities will be much accentuated and will travel very close together. This gives an opportunity for equalization of temperature by thermal conduction with consequent dissipation of energy.

These were questions which I had proposed to attack theo-

retically and experimentally in a continuation of these tests to be carried out in the autumn of 1914, when the declaration of war put an end to all work of this kind by the diversion of activities to more pressing duties. The preliminary work which I have described this evening may be of some utility, I hope, in enabling

CHART I.

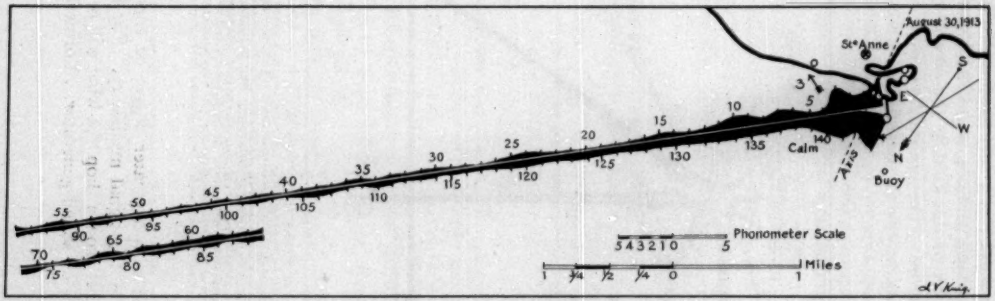


SHORT RANGE ACOUSTIC SURVEY.

The chart gives a graphical representation of the results of an acoustic survey carried out from a ship's boat in the neighborhood of the Father Point fog-signal with the Webster phonometer. The position of the ship's boat at each signal (identified by means of the numbers on the chart) was obtained by means of sextant observations. The phonometer readings at each position are plotted along ordinates at right angles to the outward and inward courses and are proportional to the pressure amplitudes in the wave. Wind directions and velocities (represented by arrows) are those registered at the meteorological station (near position 10 on Line VI). It was found that the effect of wind was by far the predominant influence on the variability of sound propagation.

engineers to proceed with a greater degree of confidence in the design and testing of fog-signal machinery. For instance, it is now possible to predict from a shop test what will be the performance of a given type of sound-generator. Formerly such a test

CHART II.

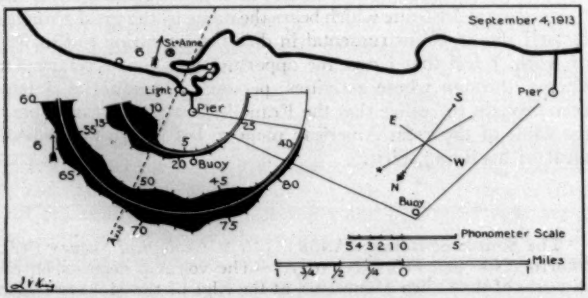


LONG RANGE ACOUSTIC SURVEY.

Observations taken with the Webster phonometer from the C. G. S. "Lady Evelyn" along an eight-mile course on a day especially favorable to the propagation of sound. Attention is directed to the periodic fluctuation of sound-amplitude along the ship's course. On some occasions the sound was lost entirely over certain portions of the course, to be recovered at a greater distance, giving rise to the so-called "silent zones." Their occurrence was found to depend on conditions of wind and weather. Wind direction is indicated by the arrows on the chart, the numbers alongside representing velocity in miles per hour.

could be determined only from an estimate from the ear, which is not able to discriminate differences of loudness when the intensities attain values far surpassed in fog-signal waves. It has frequently happened in the past that a new design of fog-alarm, thought to be promising from a shop comparison with an established type, has turned out to be an utter failure when tested by actual penetration of sound in the open atmosphere and large sums of money have been wasted in this way.

CHART III.



LONG RANGE ACOUSTIC SURVEY.

The ship was here navigated over circular courses with the fog-signal station as centre at distances of one-half and one mile. The phonometer readings are plotted along the inward and outward radii from the arc representing the ship's course. From observations such as these it is possible to estimate atmospheric propagation losses occurring between spherical surfaces at various distances from the fog-signal station. Wind velocities and directions represented as in Chart II.

By the use of the phonometer, fog-signal engineers may now study in greater detail the acoustic properties of proposed sites for the establishment of sirens by making use of an experimental diaphone installed on a lighthouse supply ship.

From a national or international point of view, the importance of the development of acoustic engineering will be readily understood when I state that in recent years a country like Canada spends per annum about two million dollars on the Lighthouse and Coast service. Of this amount as much as sixty thousand dollars has been expended annually on the installation of modern fog-signal apparatus.[18] That further developments in acoustic en-

[18] According to figures taken from the Auditor General's Report, Ottawa, 1904–1912.

gineering may ultimately be the means of enabling governments to save annually in their fog-signal service large items of expenditure is of very mediocre interest as long as ships are wrecked and lives lost owing to accidents occurring in the fog. No effort should be spared to develop fog-signal machinery whose range and dependability in all kinds of wind and weather may be still further improved, and, in my opinion, there is in this domain room for a wide field of activity of the greatest human value and scientific interest.

If the few remarks which I have been privileged to deliver this evening in the Institute which bears the name of the great Franklin himself should be instrumental in directing attention to this field of work, I feel that I owe the opportunity to the secretary, Dr. Owens, through whose activities, personal and editorial, I have been brought to realize that the Franklin Institute not only bears the name of the great American pioneer, but is also the embodiment of his living spirit.

The Source of Borax. ANON. (*U. S. Geological Survey Press Bulletin*, No. 307, February, 1917.)—The volcanic deposits on the east side of the Calico Mountains, at the edge of the Mohave Desert of California, include clays containing colemanite, a crystalline borate of lime.

Colemanite contains 50.9 per cent. of boric acid, 27.2 per cent. of lime, and 21.9 per cent. of water. The deposits near the Calico Mountains are believed to have been formed by replacement of limy beds that were laid down locally during the evaporation of lake waters, at intervals between some of the great outbursts of volcanic ejecta which formed so large a part of the Tertiary deposits. The boric acid was undoubtedly derived from fresh volcanic materials and carried to its present position by underground waters. The deposits are in two principal beds, each 5 feet thick and about 50 feet apart. These beds have been mined to a depth of 500 feet. All the borax produced in the United States is obtained from California mines, mainly from Lang, north of Los Angeles, and Death Valley. The value of borate ores produced in 1915 was nearly $1,700,000. The borax is made by heating the pulverized colemanite with a solution of sodium carbonate, forming the soluble sodium borate, which crystallizes.

THE FUNDAMENTAL PRINCIPLES OF GOOD LIGHTING.*

BY

P. G. NUTTING, Ph.D.,

Director, Research Laboratory, Westinghouse Electric and Manufacturing Company.

INTRODUCTION.

THE historical side of the subject of good lighting is extremely brief. Artificial lighting is as old as the human race, but from the most ancient times until quite recently the one principle of lighting seems to have been the elemental one of a bare sufficiency of light. Only the simpler requirements of vision were recognized, efficiency in lighting was apparently not considered at all.

We are at present in a transition stage. The lighting industries paved the way for a great advance in lighting methods by making available an abundance of light. This means in effect that practically any desired *quantity* and *quality* of light are at our command. Further, the variety of lighting fixtures is an assurance that any desired *direction* and *ratio* of *scattered* to direct light may be had. Photometry is able to supply us with any desired data on intensity, brightness and distribution. Clearly then, the time is ripe for the research engineer to determine what lighting is most desirable. He cannot be expected to draw up a general scheme of lighting any more than a bridge engineer may produce a general plan for all bridges, but general principles may be determined and laid down for the guidance of illuminating engineers.

Good lighting is that which produces good seeing. This simple definition is both broad and precise; that lighting may be good, it is both necessary and sufficient that it produce good seeing conditions. The fundamental principles of lighting must, therefore, be derived from the requirements of vision and these in turn from the laws governing the sensation caused by any given exposure of the retina to light of any given flux density and density distribution. In other words, the passage of light from a source to a re-

* Presented at the meeting of the Section of Physics and Chemistry held Thursday, November 9, 1916.

flecting object and thence to the eye and retina is all governed by simple optical laws. Nothing occurring during that passage determines whether the seeing is good or bad—seeing conditions quite satisfactory to one eye might be quite intolerable to another. But the psychophysical relations between the light entering the retina and the sensation produced are all important.

The following table may, perhaps, clear up the rather complex relation between lighting and seeing.

I. GOOD SEEING

Discrimination	*Acuity*	*Efficiency*	*Comfort*
Contrast in Detail	Sharpness of Detail	Seeing: Fatigue Light Economy	Lack of Fatigue Lack of Injury

(Related by Psychophysical Laws to)

II. RETINAL FLUX of Light

Intensity	*Distribution*	*Color*

(Deducible by Optical Laws from)

III. Objective BRIGHTNESS and CONTRAST
(Deducible by Optical Laws from)

IV. ILLUMINATION and REFLECTING POWER of Objects.
(Deducible by Optical Laws from)

V INTENSITY and POSITION of Light Sources.

This bald outline of the principles of illuminating engineering emphasizes the importance of those psychophysical relations between light flux (in, say, lumens per square millimetre) at the retina and the corresponding perceptions. It indicates why good lighting cannot be defined in terms of illumination and reflecting power of objects illuminated, nor yet in terms of brightness and contrast in the field viewed. Retinal flux of light, even, is not sufficient to insure good seeing—the lighting must be such as to give the desired discrimination, acuity, efficiency and visual comfort, and a specification in terms of even retinal flux would fail to take account of the entire visual factor. Under certain conditions an increase in brightness and clearness may be obtained by actually *decreasing* the illumination.

Good lighting then is that which produces good seeing conditions, and good seeing is that which enables the average normal human eye to best distinguish details, in high light, half-tone and shadow, with at least moderate visual efficiency and comfort. Some vision under difficult seeing conditions is by no means objec-

tionable, in my opinion, since over-protection is a sure cause of deterioration.

Now the ability of the eye to distinguish detail is not a fixed constant nor yet is it a function of a single variable, as in the corresponding case of the photographic surface; it depends upon (1) the absolute brightness of the object viewed, (2) upon the brightness or darkness of its surroundings (*i.e.*, upon peripheral vision), and (3) upon the brightness of objects just previously viewed (adaptation). Let us consider each of these relations in turn, concluding with some practical applications of the principles and data discussed.

VISION WITH STEADY, NEARLY UNIFORM, FIELD BRIGHTNESS.

It is commonly known that the eye automatically adjusts its sensibility to the general brightness of the field viewed. Over a wide range of moderate intensities we are able to distinguish slight differences in light and shade about equally well. At lower brightness levels and at very high, considerably larger differences are the least that can be distinguished, while near the lowest perceptible intensities we can see but mere outlines. The whole range of intensities over which the eye operates, from the threshold of vision up to the blinding brightness which is the upper limit of adaptation, is roughly ten billion (10^{10}) to one, from 0.000001 millilambert at the threshold up to 10 lamberts. The latter brightness is about that of a sheet of white paper under direct normal sunshine. The clear noon sky, the full moon and a gas flame are each about one lambert in brightness; the lower limit for comfortably reading ordinary print is about 0.01 millilambert. Visual sensibility itself varies by a factor of about 10^7 while the field viewed varies by 10^{10}.

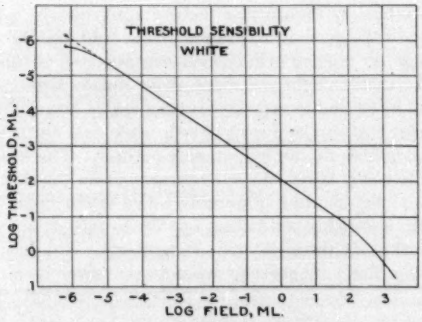
At any given general level of brightness, say that indoors under artificial lighting (about 1/10 m.l.), three visual constants are of chief interest: the lowest perceptible brightness, the least perceptible difference in brightness and the highest tolerable brightness. These constants are a measure of what we can see and of how well we can see at that brightness level.

Threshold Sensibility.—To obtain the lower limit of vision we first view a large white surface of known brightness until thoroughly adapted, then suddenly drop this brightness to another very much lower which is just visible. This threshold, of course,

varies enormously with the brightness of the field to which the eye is initially adapted. The complete curve for white light is shown in Fig. 1. Plotted logarithmically the curve is a straight line from the threshold of vision up to about 100 m.l., then falls off more and more. The lower limit of adaptation is the threshold. The upper limit of adaptation, also where the least that can be seen is the whole, is where the threshold curve crosses the 45-degree line, that is, where the threshold brightness is equal to the field brightness. This is at a little over 10 lamberts.

This instantaneous threshold is a proper measure of the absolute sensibility of the retina, since it is determined by the condition

FIG. 1.



Variation of sensibility with brightness.

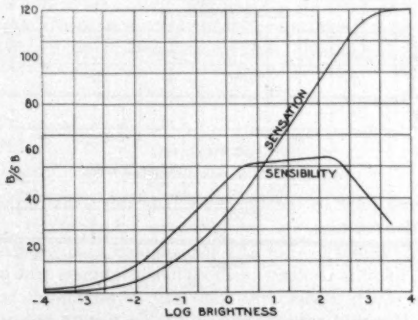
of the visual surface and nerves. The absolute threshold at the lower limit of vision is a measure of the absolute photochemical reactivity of the retina. The straightness of the threshold curve is an indication of the simplicity of the relation between the state of the retina and the flux density upon it.

Discrimination.—Distinguishing slight differences in light and shade, picking up detail, is the characteristic function of the eye. This depends somewhat upon sharpness of definition and largely upon differences in color, but is principally a matter of contrast in brightness. Contrasts are ordinarily due either to differences in reflecting power or to partial shadows. Vision is best when contrasts are about 10 to 1, but is entirely comfortable with contrasts

as low as 51:50 or as high as 20:1. Where contrasts are as high as 100:1, vision is not as acute and far less efficient than when they are moderate.

The relative efficiency of the eye under various contrasts and brightnesses is doubtless roughly measurable by accuracy and fatigue methods, but the fundamental datum in this field is the difference sensibility, resolving power for light and shade, discrimination, or whatever it be named. This datum is readily obtainable by photometric methods. It is the ratio (inverse) of the just perceptible difference in brightness to the brightness at which it is measured, B/dB. This is simply the reciprocal of the photometric difference determined twenty years ago by König and since then by numerous other observers. This curve of just perceptible dif-

FIG. 2.



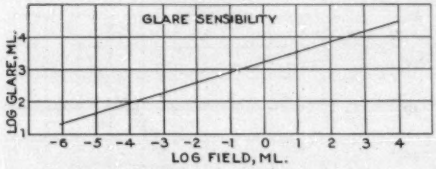
Discriminating power and sensation at various brightnesses.

ference has the general form of a sled runner. Recent work has but confirmed its general shape, established it in definite brightness units and determined the effect of time or adaptation.

The discrimination curve (Fig. 2) is the reciprocal of the fractional difference curve of the preceding slide. It rises slowly from the threshold up to a value of about 60, remains nearly constant for a considerable range, then falls rapidly at high, glaring intensities. The integral of the just noticeable difference, which is the fundamental relation between sensation and stimulus, is the sloping curve.

These curves may be compared with the corresponding reaction and discrimination curves for a photographic plate, a Seed 30, for example. The inclined curve is density of negative plotted against logarithm of exposure, the other is its derivative, the difference sensibility of the plate. The slopes are much steeper and more symmetrical than in the case of the retina, while the region of normal exposure is just about as extensive. The general similarity of the visual and photographic curves is very striking and indicates a similarity in the photochemical processes involved. The fact that the eye reaction is a function chiefly of intensity, while the photographic is a function of total energy (intensity × time), is doubtless due to restoring forces in the retina that are lacking in the photographic emulsion. The length

FIG. 3.



Glare sensibility at various brightness levels.

of the initial slope of the eye curve indicates a distinctive initial phase of the reaction.

Glare Sensibility.—For any eye, adapted to any given brightness level, there is another much higher brightness just painfully bright, in which moderately contrasty detail cannot be distinguished. It would appear that only the roughest measurements of the glare limit would be possible, but since this datum is of the greatest importance to illuminating engineers, a determination was attempted. The three observers obtained quite concordant results, the mean showing a linear relation between log glare and log field brightness. (Fig. 3.)

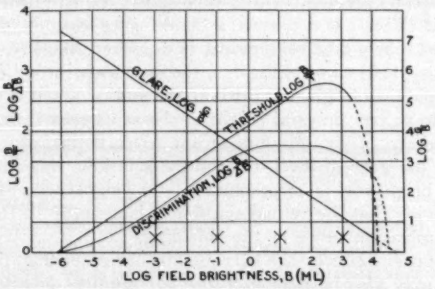
The range covered by the data is from near the absolute threshold (10^{-6} m.l.) up to nearly the upper limit of adaptation (10 lamberts). By practical experience we know that the eye is unable to adapt itself to a snow field under a direct sun and breaks down under long exposure. This, then, is the limit of the metabolic processes of the retina.

A brief summary of the data on threshold limit, discrimination and glare limit is given below.

Field Brightness.		Difference Fraction.	Discrimination Factor.	Threshold Limit.	Glare Limit.
0.000001 m.l.		(1.00)	1.0	0.00000093 m.l.	20.1 m.l.
0.00001		(0.66)	1.5	0.0000042	40.7
0.0001		0.395	2.5	0.000019	89.
0.001	(E.N.)	0.204	4.5	0.000087	86.
0.01		0.078	12.8	0.00039	400.
0.1	(I.N.)	0.037	27.0	0.00174	810. m.l.
1.0		0.0208	48.2	0.0081	1.66 l.
10.	(I.D.)	0.0174	57.5	0.036	3.47
100.		0.0172	58.1	0.28	7.25
1000.	(E.D.)	0.0240	41.7	2.15	14.45
10000.		(0.048)	(20.9)	(232.)	30.90

For example, an average eye adapted to a field brightness of 0.1 m.l. can just see a contrast of 1.037: 1—the discrimination is about half (27/57) its maximum value. The deepest shadow in

FIG. 4.



Threshold, discriminating power and glare sensibility at various levels.

which it can see anything is 0.0017 m.l. in brightness and the brightest tolerable high light is 800 m.l.

The illuminating engineer is chiefly concerned with four quite distinct brightness levels, namely:

0.001 m.l. (E.N.) Exteriors at night, street lighting.
0.01 m.l. (I.N.) Interiors at night, interior artificial lighting.
1.0 m.l. (I.D.) Interior daylight lighting.
1.0 l. (E.D.) Exterior full daylight lighting.

For comparison, these data have been plotted all together (Fig. 4). Glare and threshold are here plotted as multiples and fractions of the field brightness, while discrimination is plotted logarithmically. Running up any given ordinate, the curves show (1) the least perceptible contrast, (2) the lowest perceptible brightness, and (3) the highest brightness that can be viewed with comfort. The dotted portion of the glare curve is quite certain, that of the threshold fairly so, while that of the discrimination curve we know must end between these two.

VISION IN CONTRASTY FIELDS.

The data just given refer to vision with surroundings of nearly the same brightness as the object directly viewed. When this peripheral field is much brighter or darker than the centre, vision is seriously affected. In other words, central retinal sensibility depends upon the total light striking the retina and its distribution, as well as upon the light striking the fovea. Seeing in one eye is even slightly affected by the condition of the other.

A simple experiment with a tube shows the magnitude of the peripheral effect. If we view a blank space steadily through a black-lined tube 3 or 4 centimetres in diameter and, say, 50 centimeters long, held close to the eye, the spot seen through the tube grows rapidly in brightness until at the end of about a minute it appears 50 to 100 times as bright as the same spot seen with the unshielded eye. The light flux on the fovea is the same for both eyes. If the general level of brightness is low, this increase in apparent brightness is accompanied by a heightened discrimination, showing that the retinal sensibility is actually shifted along the discrimination curve by the shielding.

The opposite effect, with surroundings brighter than the centre of view, may also be demonstrated but requires laboratory apparatus. Both kinds of non-uniform field lead to visual discomfort, both in extreme cases cause a sensation of glare. Ives' investigation of photometric sensibility showed that the maximum of sensibility is obtained with nearly uniform brightness of the whole field of view. Glare we know to be impossible in nearly uniform fields, throughout the whole range of intensities to which the eye is capable of adapting itself.

We have obtained precise data on the depression of sensibility under various conditions of the surrounding field. Having

the surrounding field dark and varying the angular size of the light central spot give curious results. If the central spot is not very bright, diminishing its size decreases the sensibility, while if it is quite bright the reverse is true. At intermediate brightnesses, varying the size of the central spot does not affect the sensibility.

EFFECT OF SIZE AND BRIGHTNESS OF SPOT ON SENSIBILITY.

Solid Angle of Bright Spots	Field Brightness 1.0 m. l.	17 m. l	170 m. l.	600 m. l.
Full	0.0064	0.074	0.29	1.2
1.0	0.0050	0.074	0.27	1.4
0.1	0.0065	0.074	0.26	1.5
0.01	0.0090	0.074	0.22	1.5
0.001	0.0125	0.074	0.13	0.84
0.0001	0.0161	0.074	0.08	0.15

The effect is most pronounced at small solid angles, and the general trend of the change produced is best shown by the curves (Fig. 5).

Aside from its angular *size* and *brightness*, the effect of a glare spot on sensibility depends upon its *position* relative to the axis of vision. Data on relative threshold are given below for a field brightness of 0.1 m.l. and a frosted lamp about 1 lambert in brightness.

Angle	0°	10°	20°	30°	40°
Relative Threshold	0.11	0.17	0.26	0.42	0.65

The (logarithmic) depression of foveal sensibility is a linear function of the angle with the axis. Beyond 50° no depression was perceptible.

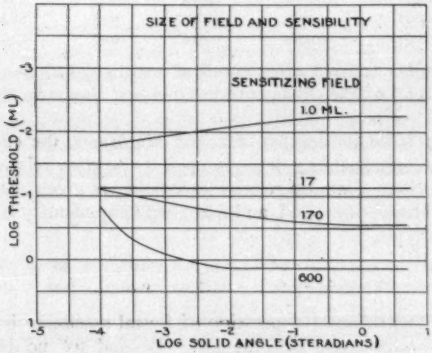
The ocular discomfort caused by a lamp flame or filament within the field of view is largely a matter of intrinsic brilliancy and is relieved by a diffusing shade. The depression of sensibility, on the contrary, is a matter of total candle power and is not relieved by a shade which merely diffuses the light. If the brightness is held constant and the area (*i.e.*, total candle power) varied, then the depression varies as the square root of the candle power or area.

ADAPTATION TO VARYING BRIGHTNESS.

Vision is practically as comfortable and acute at the mean brightness of a well-lighted interior (0.1 m.l.) as in full daylight with a mean brightness level ten thousand times as high (1 lam-

bert). The visual mechanism automatically adapts itself to the changed conditions by some means not well understood. If the brightness level is suddenly changed, adaptation is very rapid at first, then comes gradually to equilibrium. Adaptation curves have been run for times as great as sixteen hours. With our improved visual sensitometer and threshold method we have been able to study the important initial portion of these curves, readings of sensibility being taken after 0, 2, 5, 10, etc., seconds after exposure to light or darkness. In much ordinary vision the eye is constantly shifting from one object to other objects lighter or

FIG. 5.



Effect of size and brightness of spot viewed on sensibility.

darker. If adaptation from lower to higher intensities occurred at the same rate as that from higher to lower, the net depression would be nil, but such is not the case.

The following table shows roughly the rates of increase and decrease in sensibility in an ordinary case. The data refer to the change from complete darkness to a brightness of 25 m.l. and vice versa. Twenty-five millilamberts is about the brightness of a sheet of paper in a well-lighted room on a bright day. It is a brightness quite blinding to an eye adapted to darkness, yet but a thousandth as bright as the average automobile headlight.

In the experiment the eye was sensitized to one level of brightness (0 or 25 m.l.) then suddenly exposed to the other and the

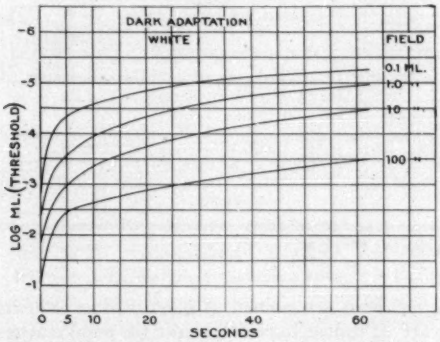
(threshold) sensibility determined at intervals by the test spot method described above.

RATES OF INCREASE AND DECREASE OF SENSIBILITY.

Time	B_0=0, B=25 m.l. Sensibility decrease	B_0=25 m.l., B=0 Increase
1 second	2.1 times	1.6 times
2 seconds	4.2 "	2.6 "
5 "	16.2 "	7.6 "
10 "	58. "	14.4 "
10 minutes	120. "	20.9 "

For example, if an eye adapted to darkness be suddenly exposed to 25 m.l. its sensibility drops to 1/16 in 5 seconds and a subsequent rest of 10 seconds will by no means restore its sensibility. A great deal more data of this nature is desirable.

FIG. 6.



Dark adaptation. White light. Various initial brightnesses.

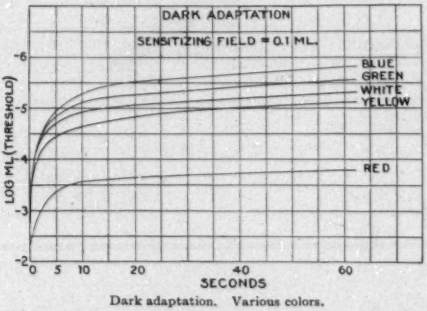
Dark adaptation has been quite thoroughly investigated. Starting with the eye sensitized to a given level of brightness, the light is suddenly removed and the rate of growth of sensibility in darkness is noted. This rate of growth varies with (1) the initial state of adaptation, (2) the color of the light used, and (3) the contrast used in the test spot. It varies also to some extent with the individual, his previous states of adaptation, extending back several hours, with the degree of attention exercised and other

similar causes, but the first mentioned variables are by far the most important in practical problems.

In Fig. 6 are shown characteristic adaptation curves for white light and initial adaptation to brightness of 0.1, 1.0, 10 and 100 m.l. These curves run sensibly parallel for the first minute, but, of course, eventually merge and continue as a single curve similar to that of Fig. 6.

The initial adaptation is to some extent counteracted by the opening of the pupil. Precise shutter test measurements on the rate of pupil opening have yet to be made, but from adaptation curves run with and without a fixed artificial pupil we know that the greater part of the change in diameter occurs in the first half second. The pupil diameter corresponding to each steady field

FIG. 7.



Dark adaptation. Various colors.

brightness has been determined as given in the following table. Both ends are, of course, horizontal since the pupil reaches definite maximum and minimum diameters.

Field Brightness (m. l.)	.0001	.001	.01	0.1	1.0	10	100	1000
Diameter of Pupil (mm.)	6.1	5.9	5.7	5.4	4.7	3.7	2.8	2.1

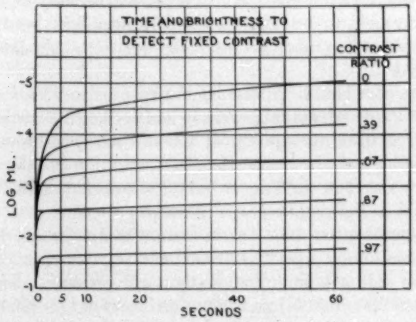
Starting with the same initial sensibility but different colors, red adapts least and most slowly, yellow next, then white, green and blue (Fig. 7). Blue sensibility increases twice as rapidly as red and proceeds twice as far.

Most interesting from a practical standpoint are adaptation curves run with certain definite contrasts in the test spot. A strip of neutral gray film of known opacity is laid across the test spot

and the time noted at which it just becomes visible over a spot whose brightness is constantly regulated. We thus obtain (Fig. 8) an adaptation curve for each degree of contrast. With contrasts so slight as 97:100 (3 per cent. absorption in the contrast strip) there is hardly any gain in visibility, while heavier contrasts increase more and more in a given time.

On entering a dimly lighted room from one brightly lighted, the heavier contrasts first become visible, then the more moderate contrasts. The faintest contrasts fail to become perceptible even

FIG. 8.



Dark adaptation. Various contrasts.

after a long wait. Out-of-doors at night, not only detail in shadows but any detail involving weak contrasts is not perceptible.

If we take a vertical cross section (at 10 seconds, say) of a group of contrast-adaptation curves, there is obtained a relation between just perceptible contrast and brightness at constant time of adaptation. This is the Fechner fraction again; photometric sensibility curves have actually been obtained in this manner.

APPLICATIONS TO PRACTICAL LIGHTING.

The objective of all lighting is to secure visibility of detail in those objects to which attention is directed. The detail to be observed may be: (a) mere outlines of large objects, such as are required in riding along a country road at night, (b) the outlines of small objects, as in reading, or (c) the minutest detail which the eye is capable of resolving. As examples of Class C

may be mentioned photo-engraving, drafting, sewing and many other arts and crafts where critical judgment is required.

For seeing of Class A but little illumination is required. The light of a high full moon supplemented perhaps by a little local lighting is ample if not ideal. Operating so near the threshold, the retina is incapable of rendering detail except with harsh contrasts. Little attention need be paid to the direction of the lighting or to the ratio of specular to diffuse light, since the eye is operating at low efficiency anyway. Spot glare should be carefully avoided, however, since the retina is in a supersensitive condition and but a little glare will so depress sensibility as to render objects invisible. Ordinary automobile headlights and lighting units visible at less than 30° from the horizontal should be carefully avoided.

Seeing of Class B represents the vast majority of ordinary working conditions, reading, writing and accounting coming under this class, as does the lighting of school-rooms, auditoriums and shops. Contrasts are ample, the observation of fine detail is not required. Careless lighting is only too tolerable and therefore really efficient lighting none too common.

The specification of a discrimination factor of not less than half the maximum is perhaps reasonable for this class of seeing It follows that any illumination that will produce a brightness level of not less than 0.1 m.l. nor over 7000 m.l. is tolerable, although brightnesses ranging from 1 to 250 m.l. are to be chosen.

The really difficult problems in this class of lighting are providing the proper ratio of direct to diffuse light and giving both the proper direction. Comfortable, acute vision requires that there be neither extreme high lights nor dense shadows within the field of vision and that the details to be observed present sufficient but not too great contrast, that is, contrasts of over 50: 49 and under 50: 1. Indirect lighting will get rid of the shadows and extreme high lights, but almost completely suppresses contrasts, particularly on glossy or uneven surfaces. Glossy surfaces it covers with a light veil of specularly reflected light, uneven surfaces becoming less visible by suppression of shadows.

With bright daylight in the open, the scattered light from the sky contributes from about 16 to about 40 per cent. of the total light falling on a horizontal or vertical surface. On cloudy days nearly all the light has 180 degrees diffusion and on clear days

shadows are lighted chiefly by sky light. The golden mean for good average seeing is probably not far from 30 per cent. diffused light.

If we view a landscape on an ordinary clear day through yellow, amber or green glass, the view will appear very much brighter and more clean cut. The old explanation was that the yellow glass cuts out the purple haze, but it does a great deal more than that—it eliminates the diffuse sky light in all shadows because these shadows are lighted by blue light, leaving the directly reflected sunlight almost unaffected because the blue in it is but a small part of its total luminosity. The consequence is that shadows are deepened and contrasts everywhere increased, producing a brightening effect. Viewing through blue glass has precisely the opposite effect.

While cutting down brightness with an absorbing yellow glass may produce the appearance of enhanced brightness, added light may produce the sensation of lowered brightness. If a room lighted by high, well placed direct lighting units be further lighted by a little highly diffused illumination, the sensation produced is one of lowered brightness due to increased brightness of shadows and general decrease in contrasts. In the black tube experiment shielding the peripheral retina from light produced a sensation of increased brightness fifty to one hundred fold on the unshielded portion, although the total light entering the eye was much less.

The proper proportion of direct to scattered light is readily obtainable in either artificial or daylight lighting. The lighting units must further be so disposed as to give a direction adapted to the service to be rendered. In art galleries the glossy surfaces to be viewed are plane and nearly vertical, hence high angle lighting is indicated. In machine shops, the glossy surfaces to be considered are largely horizontal cylinders and the lighting may well be of low angle and very diffuse.

In street lighting there exists a very persistent custom of leaving the illuminant in full view and of allowing a large fraction of the light to escape upward. A bright illuminant within the range of vision is a powerful depressant of visual sensibility, particularly if near the axis of vision, so that the customary arrangement is hardly conducive to visual efficiency. In interiors both very good and very poor lighting are common in both daylight and artificial lighting.

In the highest class of lighting (Class C, above), where the

minutest detail is to be critically observed, only the very best lighting conditions will prevent visual discomfort and eye strain. Fine needle work requires perhaps as high class lighting as any. Interest centres upon a mass of fine bright images formed by the needle and fibres of textile goods. If all the light is diffuse, these images broaden and merge and shadows disappear. Vision is strained by the attempt to pick up faint contrasts just at the limit of the power of discrimination. The most suitable lighting is that limited to nearly a single direction and that quite elevated. What is seen is a mass of cylindrical images of the source, and if the source subtends but a small angle these images are sharp and contrasty.

In short, the very best seeing requires an abundance of nearly unidirectional light. The light from the sky through high, well spaced windows is very nearly ideal. Indirect lighting from numerous sources is very bad. Semi-indirect lighting with units closely assembled and at one side is probably the best form of artificial lighting. No part of any lighting unit within the range of vision should exceed 250 millilamberts in brightness nor should contrasts ordinarily visible exceed 100 : 1.

Our whole discussion has been an attempt to elucidate the principles of efficient lighting, efficient in the double sense of making the best possible use of the light and efficient in enabling the eye to operate under the most favorable conditions. Extremists have, on the one hand, tolerated any lighting that did not cause permanent injury to the eyes, and on the other have raised trivial objections to even minor causes of discomfort. I have no sympathy with either view; what should be done in my opinion and what is worth our best consideration and effort is the relief of our over worked and much abused eyes from the wear and tear of the bad lighting conditions which we have ourselves put upon them. It would be unwise and unnecessary to relieve them of all discomfort at all times—that would surely result in a deterioration of the adaptability of the eye itself. Our standard in my opinion should be the comfort of out-of-doors daylight lighting; abundant light 30 per cent. diffused and—by far the most important—but moderate contrasts anywhere. Under but tolerable lighting conditions the eye is wonderfully adaptable and efficient and it is to be hoped that within the near future it will be relieved of the many trying conditions under which it is now called upon to operate.

THE ORGANIC NITROGEN COMPOUNDS OF SOILS AND FERTILIZERS.*

BY

ELBERT C. LATHROP, Ph.D.

USUAL AND UNUSUAL NITROGENOUS SOIL CONSTITUENTS.

Histidine, hypoxanthine, cytosine, xanthine, nucleic acid, creatinine, cyanuric acid, or its isomer cyamelid, may then be considered to be organic nitrogenous constituents commonly occurring in soils.

Arginine, lysine, adenine, choline, trimethylamine may be considered at the present time to be nitrogenous constituents unusual to soils, inasmuch as they occur infrequently in soils. These compounds may either not be normally formed by the processes of change taking place in the soil, or if they are formed they are probably very quickly changed into other compounds, for example, arginine into ornithine and urea, or adenine into hypoxanthine. Regarding tetracarbonimid and urea no statement can be made at present.

THE CHANGES PRODUCED IN THE NITROGENOUS ORGANIC MATTER OF SOILS BY THE PROCESS OF PARTIAL HYDROLYSIS.

Having established the fact that a number of the simpler primary protein decomposition products are normally occurring soil constituents, likely to be found in all soils under agricultural occupation, it seemed desirable to see if it might not be possible also to demonstrate the presence in soils of compounds more complex than any of these. Two methods exist of determining this experimentally, first, directly, by isolation of the complex compounds, and, second, by isolation of their component units, produced by treatment of the soil after previously establishing the absence of these units in the untreated soil. The second method is the one employed in this investigation.

The soil treatment used in decomposing these more complex

* Contribution from the Laboratory of Soil Fertility Investigations, communicated by Dr. Oswald Schreiner and published by permission of the Secretary of Agriculture.

Continued from page 206, February issue.

nitrogen compounds was steaming. The effect which moist heat produces upon pure protein material is that of partial hydrolysis, the extent of the hydrolysis depending on the temperature reached and the length of treatment. The effect which heat has upon soils is a subject which has been, and is, rather prominently before agricultural investigators. It is a subject which has been receiving increasing attention, particularly from the point of view of sterilization or partial sterilization of the soil. Since heat activates the changes going on normally in soils, it is obvious that a study of heated soils also throws light upon the biochemical changes taking place in soils under field conditions.

Notwithstanding the fact that some of the results obtained by some of the investigators[1] on this subject are contradictory, especially in regard to the effects of steam sterilization of soils on crops, they seem to warrant the following conclusions:

By steam-heating the physical, chemical, and physiological properties of soils are more or less altered. The chemical changes consist in the increase in soluble matter in the heated soils. This is partially of an inorganic nature, potash and phosphoric acid being mainly determined, but the largest increase is in the organic matter rendered soluble. Ammonia is formed by the reduction of nitrates to nitrites and ammonia, but especially from the decomposition of organic matter. Large amounts of nitrogenous matter are made soluble and apparently more available for plant use, and carbon dioxide is produced in large quantities.

The nature of the chemical changes observed by these investigators is not made clear, although a number of suggestions, or

[1] In this connection see the following: A. Baumann, 1887; Bolley, 1911; Darbishire and Russell, 1907; Deherain and Demoussey, 1896; Dietrich, 1901; Fletcher, 1910; Frank, 1888; Hérbért, 1889; Hiltner and Störmer, 1903; Hutchinson and Miller, 1911; Kasseroff, 1906; Kelly and McGeorge, 1913; Koch and Lüken, 1907; König, Hasenbaumer and Coppenrath, 1906, 1907; Laidlaw and Price, 1910; Lathrop, 1912; Lemmermann, Fischer, Kappen and Blanck, 1909; Liebscher, 1893; Loew, 1909; Loew and Aso, 1907, i, ii; Loges, 1886; Lyon and Bizzell, 1909, i, ii, and 1913; Peterson, 1911; Pfeiffer and Frank, 1896; Pfeiffer, Frank, Friedlander and Ehrenberg, 1909; Pfeiffer, Guttermann and Theile, 1910; Pickering, 1908, i, iii; Richter, 1896; Rudd, 1893; Russell, 1910; Russell and Hutchinson, 1909; Russell and Petherridge, 1912, 1913; Schmoeger, 1893; Schreiner and Lathrop, 1912; Seaver, 1909; Seaver and Clark, 1910; Selby, 1896; Stone and Smith, 1901, 1902; Stone and Monahan, 1904; Stuart, 1905; Vogel, 1914; and Wilson, 1914.

hypotheses, have been put forward. These concern themselves partly with an explanation of the increase in mineral constituents, due to altered absorption qualities for these constituents brought about by heat and by the greater hydrolysis or solubility of the minerals under the conditions of high temperature. Nearly all have particularly noticed the greater increase in soluble nitrogen and coincident with this the increase in soluble organic matter. It is these latter observations which have been the source of most of the speculations to explain the increase and decrease, as the case may be, of plant growth on soils thus heated. These views are usually coupled with the biological idea which furnished the motive for the experiment.

In no case has any definite compound been obtained, either as an end or intermediary product of the changes brought about by the heat, and the subject is left in the same state of indefinite generalizations in which soil organic matter or humus found itself in the course of the past half century. In view of this lack of knowledge concerning the chemistry of soil organic matter itself, and its transformations under ordinary conditions, it is not to be expected that changes like the above could have been clearly defined.

The investigations of the past few years have brought with them an increasing knowledge of the nature of organic matter, especially with regard to the isolation and identification of specific chemical compounds from soil, so that the biochemical changes taking place in soil are becoming clear. In connection with these investigations methods for the recognition or isolation of specific chemical compounds have been developed. With such knowledge at hand, it seemed possible to go one step farther and show the changes produced in soil organic matter in the process of sterilization by heat, and thus be able to interpret these changes.

THE SOILS STUDIED.

The soils used in this investigation are two types of the Coastal Plains Soil Province, known as Elkton silt loam and Sassafras silt loam. These two soils were collected from the same farm, about four miles east of Easton, Md., April, 1911. The samples taken were from several spots within a radius of 40 feet in each case and were collected in adjoining fields within 150 yards of each other.

Although these soils have the same geological origin, they are rather widely different in physical and chemical characteristics, and in fertility. The differentiation is apparently due to drainage conditions. While the two soils are very distinct in color, and in general agricultural value, the change from one to the other is frequently so gradual that it is difficult to draw a distinct boundary line. The samples taken are strictly typical of the types.

Analysis shows that these two soils contain practically the same amount of organic matter, the Elkton 2.25 per cent., and the Sassafras 2.24 per cent.; the former contains 0.13 per cent. of carbonates, expressed as carbon dioxide, and the latter only 0.03 per cent. The two soils are both acid to litmus paper, the Sassafras soil being slightly the more acid of the two. In regard to their oxidizing power and their catalyzing power, that is, their power to decompose hydrogen peroxide, they are both very weak, the Elkton showing none at all and the Sassafras only a little. They both contain practically the same percentage of total nitrogen. When the soils are boiled with hydrochloric acid and the different forms of nitrogen determined according to the method of Osborne and Harris (1903), the soils show only trifling differences. The results obtained by this method of analysis are presented in Table I.

TABLE I.

Different Forms of Nitrogen in Elkton Silt Loam and Sassafras Silt Loam. Results Expressed in Per Cent. of Total Nitrogen in Oven-dried Soil.

Form of Nitrogen.	Elkton.	Sassafras.
Per Cent. of Total Nitrogen in Soils	0.0859	0.0869
Total N in solution	91.83	91.08
N insoluble in HCl	8.17	8.92
N as NH_3	0.83	2.27
N as Amides	12.06	12.45
N as Melanin N	18.96	19.63
N as Diamino acids	5.53	7.17
N as Monoamino acids	54.45	49.56

From Table I it is apparent that the only difference worthy of mention is the fact that the Sassafras soil contains slightly more ammonia than does the Elkton soil, but this is much too small to account for the differences in fertility. It is apparent from all of the analytical data that, in a general way, these two

soils are very similar in their organic composition, and that no methods of analysis, excepting the actual isolation of the various definite organic compounds which compose the organic matter, will show wherein this difference in their organic composition lies.

The methods of farm practice have been identical with these soils, and each has received the same kind of débris, manures, plant residues, etc., which by processes of decay go to form the organic matter of soils. If, therefore, differences in the organic matter of these soils are shown to occur, they must be the result of different processes of decomposition in the soils.

THE METHOD OF HEATING.

For the purpose of heating the soils an autoclave such as is in general use was employed. The autoclave is of copper, so constructed that it may be automatically kept at 30 pounds steam pressure for any given length of time. The soils were heated in one-gallon stoneware jars placed in the autoclave in a metallic rack, the jars standing one above the other, the lower one being about 4 to 5 inches above the bottom of the autoclave. These jars held approximately 10 pounds of soil. The soils were heated at 30 pounds pressure for 3 hours, at a temperature of about 135° C. The soils were treated with alkali just as soon as they had cooled to room temperature, so that only the changes caused by the immediate heating were under observation.

METHOD OF EXTRACTION.

Owing to the small amounts of organic matter in these soils and also to the fact that not all of this organic matter can be extracted, large amounts of soil were worked upon. Generally 40 to 50 pounds of soil, both heated and unheated, were extracted with 2 per cent. sodium hydroxide solution. No attempt was made to study the humus precipitate. The chief interest in the work centred in the nitrogenous compounds, especially those rendered soluble by heating of the soil. Such compounds would appear chiefly in the alkaline extract and later in the acid filtrate from the humus precipitate.

EXPERIMENTAL RESULTS.

In harmony with the observations of other investigators, the total amount of water soluble solids was increased by the heating. The soils by the bridge method showed the following

content of total soluble solids: The normal Elkton soil, 184; the heated Elkton soil, 336; the normal Sassafras soil, 151; the heated Sassafras soil, 270 parts per million of dry soil. It will be noticed that the poorer soil, namely, the Elkton, showed the higher content in both heated and unheated condition. No further examination of the saline material was made.

By heating, the acidity of both soils was increased towards litmus paper. It should be noted, however, that ammonia and amines were also formed in the process of heating, as was indicated by the fishy odor upon adding the alkali in the process of extraction. The results obtained in isolating and identifying the organic nitrogenous constituents extracted from the heated and unheated soils are concisely given in Table II.

TABLE II.

Organic Nitrogenous Compounds Isolated from Unheated and Heated Soils.

Elkton silt loam.		Sassafras silt loam.	
Unheated.	Heated.	Unheated	Heated
Nucleic acid	Nucleic acid	Nucleic acid	Nucleic acid
Xanthine	Xanthine	.....	Xanthine
.....	Hypoxanthine	Hypoxanthine	Hypoxanthine
Adenine	Adenine	.....	.....
.....	.....	.....	Guanine
.....	Cytosine	.....	Cytosine
Histidine	Histidine	Histidine	Histidine
.....	.....	.....	Arginine
Creatinine	Creatinine	Creatinine	Creatinine

The results in Table II show only whether the organic compound was present or not. While no quantitative methods for the separation of these compounds from soils exist, owing to a great variety of difficulties which will not be discussed here, still in the work it was possible to distinguish between very small amounts and larger ones.

As seen from the table, the nucleic acid was found in both soils, in the heated as well as in the unheated samples.

Xanthine was found in both the heated and unheated Elkton soil, but in larger quantity in the heated soil. In the case of the Sassafras soil it was found only after heating.

Hypoxanthine was not found in the Elkton soil, but after heating a small amount was obtained. The Sassafras soil contained this constituent, but its quantity was much increased on

heating the soil. In both cases the heating increased the amount which could be obtained.

Adenine was found in small amounts in the Elkton soil, but was not obtained from the Sassafras. Heating effected no change in either case.

Guanine was found only in the Sassafras soil and is of especial interest, since this is the first time that it has been encountered in soil.

Cytosine, it is interesting to note, was found only in the heated samples of both soils. It was obtained in much larger amounts in the case of the heated Sassafras soil than in the case of the heated Elkton soil.

Histidine occurs in both soils and a slight increase was noticed as the effects of heat.

Arginine, on the other hand, was found only in the heated Sassafras soil.

Creatinine was present in all cases.

NUCLEOPROTEIN DEGRADATION PRODUCTS.

If the principles discussed in an earlier section of this paper in regard to the breaking down of nucleoproteins and of nucleic acids be applied to the interpretation of the results obtained by heating the Elkton and Sassafras soils, it becomes evident at once that hydrolysis of the nucleic acids of these soils has taken place. This is evidenced by the fact that in each case there was a diminution in the amount of nucleic acid obtained from the soils, and by the increase both in quantity and in number of the nucleic acid bases.

In the Elkton soil unheated, adenine and xanthine were found; on heating, the amount of xanthine increased, adenine was found as before, and in addition hypoxanthine appeared. The hypoxanthine had been formed by a nucleoside containing this base. The fact that it did not appear in the unheated soil may be due to an arrested decomposition of its antecedents, or to the fact that it has changed into xanthine or lower nitrogenous compounds. Similarly, the appearance of cytosine in the heated soil is undoubtedly due to the same cause, the action of heat on antecedents containing it.

In the Sassafras soil the changes are even more definite. In the unheated soil the only base found was hypoxanthine, but

after heating there appeared guanine, xanthine and cytosine, as well as a larger amount of hypoxanthine. The absence of guanine and xanthine in the unheated soil would seem to indicate that their antecedents were not subject to further decomposition under the existing soil conditions, or else they were rapidly changed into uric acid, urea, ammonia, etc.

These two soils, as already mentioned, have had the same general field treatment and have received the same kind of organic matter in the form of manures and crop débris, so that the nucleoproteins, nucleic acids, etc., which have entered into these soils, have been practically the same. The different results in the heated as well as in the unheated soils can only show that the decompositions occurring normally under the two different soil environments are biochemically different.

One difference between the two soils is found in the fact that the Elkton soil contains no antecedent compound which will yield guanine by heating. This fact may be explained by the assumption that the guanine antecedent, possibly guanosin, is changed to a xanthine antecedent in the soil. Color is lent to this assumption by the fact that xanthine is found in both the unheated and heated Elkton soil, while guanine, as well as xanthine, is found in the heated Sassafras soil.

Another difference is in the adenine. This is found in Elkton soil and not in Sassafras soil, and any antecedent bodies seem to be absent from the latter soil. Hypoxanthine, on the other hand, into which adenine or its antecedents may change, is absent from the Elkton soil but present in the Sassafras.

Cytosine antecedents are present in both soils. The fact that cytosine is not found in the unheated soils may again be due to the permanency of the antecedent under both soil conditions, or else to the presence of factors, either chemical or biochemical, which have transformed it into uracil. Whether uracil exists in these soils, or, in fact, any other soil, cannot be experimentally determined at present, owing to lack of characteristic derivatives or properties of uracil, although it seems probable that it must exist at least under certain conditions.

PROTEIN DECOMPOSITION PRODUCTS.

Two of the final products of protein hydrolysis appear in the present investigation. These are arginine and histidine. The latter was found in both soils, unheated and heated, but was

found in greater amounts in the heated soil. Arginine was found only in the heated Sassafras soil. There is present, therefore, in the Sassafras soil a protein complex which acts as the antecedent of arginine. The question then remains, why is arginine absent from the unheated soil, and also, why is this antecedent body absent from the Elkton soil? Arginine, although a very common dissociation product of proteins, has, nevertheless, been found in only two other soils. This is rather peculiar in view of the fact that its close associate, histidine, has been found very often, a fact which is best explained on the supposition that arginine is very susceptible to change through biochemical influences. For instance, Kiesel (1909) found that the arginine in the juice of the green sprouts of lupine disappeared in the course of a four weeks' autolysis. In regard to the second part of the question as to the absence of any direct antecedent body, no very definite statement can be made, but it seems reasonable, since there is protein material in the soil, that the change of this material has not proceeded to such a stage that arginine could be produced by such a procedure as the one here employed. In other words, the biological factors in the Sassafras soil were such as to furnish an intermediary product which was dissociable by heat, and more readily decomposable in the soil. From this it would again appear that the biochemical factors are somewhat dissimilar under field conditions.

Concerning creatinine, nothing is known as to its immediate antecedent compounds and no special lesson can be learned from the occurrence of this constituent in these soils.

THE DECAY OF PROTEINS IN THE SOIL.

That constant decomposition of proteins is going on in agricultural soils is clearly shown by the two preceding investigations. This is evidenced, first, by the fact that a number of primary protein decomposition products are regularly occurring soil constituents, and by the additional fact that side by side with these simpler nitrogenous compounds there are present in soils, complexes, themselves proteins, or nucleoproteins, or very nearly akin to these. Such evidence shows the importance of a thorough knowledge of the biochemistry of the decay of protein materials in soils in finally elucidating the changes which take

place normally in the organic nitrogenous matter of soils and the nature of the compounds which result from these changes.

This subject is not only of theoretical importance, but is of practical value as well. Not only do proteins from the débris of plants growing in the soil accumulate there, but there are added to most agricultural soils stable manure, organic fertilizers and green manuring crops. All of these manures contain considerable quantities of proteins or complexes closely related to the proteins. The question of the availability or agricultural value of these fertilizers is only to be answered either by directly determining the effects of the products of decay of these materials upon the plants growing in the soil or by determining by chemical means certain facts concerning their nature. It is obvious that a knowledge of the normal decay of protein material in soils will materially aid in solving such a problem.

This investigation was undertaken for the purpose of studying the changes taking place in the protein material of a high-grade organic nitrogenous fertilizer when added to an agricultural soil. Since ammonia formation is but one step in this process, it becomes of interest to know from what portion of the protein molecule this ammonia is formed; for how long the protein itself or the primary decomposition products of the protein can persist in the soil, and finally to gain some insight into the nature of the compounds formed by the action of the micro-organisms in their life processes.

THE PROTEINS STUDIED.

Dried blood, which was chosen for this investigation, is composed almost entirely of various animal proteins and the commercial product is of fairly constant composition. Abderhalden (1898) reports figures on the composition of the blood of cattle, sheep, pigs, horses, and goats, which show that a mixture of the blood of these animals should contain about 200 parts of solid matter per 1000 parts of blood. Of these solids about 54 per cent. is hemoglobin, and about 32 per cent. albumin, or approximately 86 per cent. is composed of proteins, exclusive of any nucleoproteins or nucleic acids, which undoubtedly are also present.

The dried blood used in this investigation was purchased in the open market and contained 13.92 per cent. of total nitrogen.

Two samples of dried blood were hydrolysed by boiling with hydrochloric acid and the various forms of nitrogen in the hydrochloric acid extract were then estimated according to the nitrogen partition method proposed by Van Slyke. The results so obtained are presented in Table III. Cystine nitrogen was not determined and the small amounts of cystine nitrogen in the blood would be included with nitrogen in the form of arginine, histidine, and lysine.

TABLE III.

The Forms of Nitrogen in Dried Blood and in the Experimental Soil. Results Expressed in Per Cent. of Hydrolysable Nitrogen.

Form of Nitrogen.	Dried Blood	Soil
Amide Nitrogen	6.854.	7.008
Melanin Nitrogen	2.60	4.767
Arginine Nitrogen	7.517	7.601
Histidine Nitrogen	12.523	12.366
Lysine Nitrogen	11.517	10.093
Monoamino Nitrogen	57.057	58.220
Non-amino Nitrogen	1.479	0.312
Total	99.547	100.367

THE SOIL USED.

The soil chosen for use was a Norfolk fine sandy loam taken from a cantaloupe field near Raleigh, N. C. The soil was in a high state of cultivation and had received both mineral fertilizers and stable manure. It was found to contain 0.0301 per cent. of total nitrogen. The soil was passed through a 40-mesh sieve and dried in vacuum.

Forty pounds of soil were mixed with about three pounds of dried blood by sieving the two together until samples taken from different parts of the mixture gave duplicate analyses for total nitrogen. The total nitrogen in the soil thus prepared was found to be 0.8945 per cent. The ammonia in the prepared soil was found to be 0.0005 per cent.

The soil was made up to a 10 per cent. moisture content and was kept in a stoneware jar covered with perforated wrapping paper to exclude dust. The decomposition was allowed to proceed at the temperature of the laboratory.

During the first period of 18 days the soil was maintained at a moisture content of 10 per cent. and was mixed several times by hand during that period to promote aeration. Later on, how-

ever, the soil was restored to the 10 per cent. moisture content every 5 to 8 days, and on two occasions it was allowed to dry out completely. At each addition of water to the soil it was turned out of the jar and thoroughly mixed. The total length of the experiment was 240 days, during which time samples of the soil were taken at the following intervals: (1) 18 days, (2) 44 days, (3) 86 days, (4) 148 days, and (5) 240 days.

NITROGEN PARTITION.

By the use of the methods outlined the nitrogen was separated into the following: (1) Total nitrogen in the soil, (2) total nitrogen in hydrochloric acid solution, (3) ammonia nitrogen in the soil, (4) ammonia nitrogen in hydrochloric acid solution, (5) melanin nitrogen, (6) nitrogen precipitated by phosphotungstic acid, reported as arginine, histidine, and lysine nitrogen, (7) nitrogen in the filtrate from the phosphotungstic acid precipitate, reported as monoamino acid nitrogen and non-amino nitrogen.

By subtracting the amount of ammonia nitrogen found in the soil (3) from the amount of ammonia nitrogen found in the hydrochloric acid solution (4) the amount of nitrogen in the soil in the form of the amide group in proteins or as acid amides may be obtained. This is reported as amide nitrogen. The amount of nitrogen in the soil in the form of proteins or protein decomposition products, with the exception of ammonia nitrogen, may be obtained by subtracting the amount of ammonia nitrogen in the soil (3) from the amount of total nitrogen in hydrochloric acid solution (2). This is reported as "hydrolysable" nitrogen. The amount of nitrogen in all of the various fractions was determined by the Kjeldahl method, which does not include nitrate nitrogen unless large amounts of reducing substances are present: such may be the case, however, with some of the Kjeldahl analyses, and any nitrate nitrogen, therefore, included in a Kjeldahl determination would be reported as non-amino nitrogen.

In regard to the nitrogen reported in this investigation as amide nitrogen it might be stated that it is difficult to conceive in the present state of our knowledge of any other soil compounds than the various proteins which contain the amide group, or the acid amides themselves which would resist heating *in vacuo* with calcium hydroxide and subsequently split off ammonia on heating with hydrochloric acid.

The melanins are at present undefined and no significance can be attached to the figures obtained.

The nitrogen reported as monoamino acid nitrogen includes all nitrogenous compounds not precipitated by calcium hydroxide or not volatile in its presence *in vacuo*, not precipitated by phosphotungstic acid in the concentrations used and containing a free amino group which will react with nitrous acid to produce free nitrogen.

The greatest inaccuracies occur in the diamino acid fraction, and these are distributed between arginine, histidine, and lysine nitrogen. This group includes all nitrogenous compounds which are precipitated by phosphotungstic acid, excepting ammonia and melanin nitrogen.

The nitrogen reported as non-amino nitrogen includes all nitrogenous compounds not accounted for in the above and may include small amounts of nitrogen present in the soil in the form of nitrates.

The results obtained by the methods outlined are presented in Tables V and VI.

The amount of dried blood added to the Norfolk fine sandy loam is far in excess of the amount ever used in good agricultural practice. However, this amount was found to be necessary in order to obtain accurate analytical results and to assure differences of a large enough order between the various samples of soil analyzed; furthermore, it seemed desirable to add enough dried blood protein to the soil to render the small amount of soil proteins negligible, so that only the fertilizer nitrogen would be under observation. By reference to Table III, in which the results of the analysis by the Van Slyke method as applied to the mixture of blood and soil are reported, it will be observed that the figures obtained for the various forms of nitrogen correspond very closely to those obtained from the dried blood alone, except the figures for melanin and non-amino nitrogen, but the reason for this is not altogether clear.

AMMONIA FORMATION.

Assuming that ammonification of protein material in soil must precede nitrification and denitrification and that all loss of nitrogen in this investigation is due to ammonia evaporation, nitrification, or denitrification, and that free nitrogen is not split

off from compounds other than nitrates or nitrites, then it is possible to arive at the amount of ammonia formation in the soil during each period of time. It should be stated that this is ammonia formation exclusive of ammonia assimilation, there being no way in which ammonia assimilation could be accurately determined in these experiments.

This ammonia formation may be calculated by the following equations:

Total $N - NH_3$ nitrogen in the original soil = A.

Total $N - NH_3$ nitrogen at the end of each period = B.

Then $A - B = X$, or ammonia formation during the period.

$\frac{X}{A}$ = per cent. of nitrogen changed to ammonia during the period.

In Table IV are presented the results obtained by the use of these equations.

TABLE IV.

Per Cent. of Total Nitrogen in the Soil Ammonified at the End of Each Period of Sampling.

Time in days from the beginning of the experiment.	Per cent. of total nitrogen.
18 days	18.72
44 days	54.03
86 days	72.66
148 days	78.13
240 days	78.92

THE RESULTS OBTAINED BY THE VAN SLYKE METHOD.

By comparing the results obtained by the Van Slyke analysis of each soil sample during the experiment with the results obtained on the original soil the amounts of gain or loss in the eight different forms of nitrogen can be arrived at. It is thus possible to determine how rapidly any particular form of nitrogen compound disappeared from the soil during the course of the decomposition and, further, to determine the relative amounts of nitrogen in these fractions in respect to the total amount of nitrogen present in the soil at the end of any period. When an increase in any particular form of nitrogen over the amount present in the soil during the previous period is observed, it is not possible in all cases to state the compound in which this

nitrogen existed. But when a certain form of nitrogen shows a loss during a period it is an absolute indication that that particular kind of nitrogen was disappearing or had disappeared from the soil, although the rate could not be determined. The results obtained by this analysis are presented in Table V, in which the amounts of nitrogen in the various fractions are reported in percentages of the hydrolysable nitrogen of the original soil.

TABLE V.

The Forms of Nitrogen in the Soil at the End of Each Period. Hydrolysable Nitrogen in the Original Soil = 100.

Form of nitrogen	Original soil	Time in days from the beginning of the experiment				
		18	44	86	148	240
Amide nitrogen	7.008	7.515	6.025	5.429	3.454	3.222
Melanin nitrogen	4.767	5.080	4.374	2.276	1.391	1.698
Arginine nitrogen	7.601	5.162	3.041	1.857	1.342	1.395
Histidine nitrogen	12.366	12.975	5.547	2.912	2.382	2.010
Lysine nitrogen	10.093	7.610	1.110	0.429	0.528	0.972
Monoamino acid nitrogen	58.220	40.493	18.612	8.970	7.938	7.187
Non-amino nitrogen	0.312	1.120	1.675	2.191	0.738	0.297
Hydrolysable nitrogen	100.000	79.660	40.598	24.070	17.740	16.741

The figures presented in Table VI represent the relative amounts of the various forms of nitrogen in percentages of the hydrolysable nitrogen of the soil present at the end of each period. From this table the fluctuating composition of the hydrolysable nitrogen of the soil may be followed and the final composition of the hydrolysable nitrogenous matter of the soil may be established.

TABLE VI.

Forms of Nitrogen in the Soil at the End of Each Period. Hydrolysable Nitrogen in the Soil at the End of Each Sampling Period = 100.

Form of nitrogen	Original soil	Time in days from the beginning of the experiment				
		18	44	86	148	240
Amide nitrogen	7.008	9.555	14.840	22.556	19.471	19.246
Melanin nitrogen	4.767	6.375	10.773	9.453	7.657	10.910
Arginine nitrogen	7.601	6.477	7.491	7.717	7.567	8.333
Histidine nitrogen	12.366	16.276	13.663	12.099	13.421	12.006
Lysine nitrogen	10.093	9.550	2.710	1.784	2.979	5.809
Monoamino acid nitrogen	58.220	50.812	45.847	37.264	44.745	42.922
Non-amino nitrogen	0.312	1.410	4.125	9.102	4.160	1.774
Hydrolysable nitrogen	100.000	100.000	100.000	100.000	100.000	100.000

The figures presented in Table VII show the amounts of loss of nitrogen in each form from the soil at the end of each sampling period. The amount of loss is stated in percentages of the largest amount of any form of nitrogen in the soil at any time; for example, in the case of the amide nitrogen the amount is largest at the end of 18 days, and this figure is taken as 100. In this table the word " gain " indicates an increase in the amount of nitrogen over that present at the end of the preceding period.

TABLE VII.

The Percentage Loss of the Various Forms of Nitrogen in the Soil at the End of Each Sampling Period. The Largest Amount of Nitrogen in the Soil in Each Form = 100

Form of nitrogen	Time in days from the beginning of the experiment				
	18	44	86	148	240
Amide nitrogen	Gain	20	28	55	57
Arginine nitrogen	31	60	76	83	Gain
Histidine nitrogen	Gain	58	80	82	83
Lysine nitrogen	24	89	96	Gain	Gain
Monoamino acid nitrogen	31	67	84	86	89
Hydrolysable nitrogen	20	59	76	82	83

HYDROLYSABLE NITROGEN.

During the 240-day decomposition of the dried blood in the soil a loss of 83 per cent. of the total hydrolysable nitrogen took place. At the end of 86 days the loss was 76 per cent., showing that during the latter and longer portion of the decomposition experiment the amount of hydrolysable nitrogen which vanished from the soil was extremely small.

MONOAMINO ACID NITROGEN.

During the experiment the monoamino acid nitrogen diminished from 58 to 7 per cent., or a loss of 89 per cent. of the total monoamino acids originally present in the proteins. At the end of 18 days 31 per cent. of this form of nitrogen had vanished, while during the same time only 20 per cent. of the hydrolysable nitrogen was lost. Since the monoamino acids contain more than half of the total hydrolysable nitrogen, it would appear that the relative loss from each would be about the same. The fact that there is a difference of about 11 per cent. between

the losses from these fractions leads to the supposition that nitrogen split off of the monoamino acids has been assimilated by the microörganisms in the formation of their protoplasm.

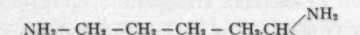
From Table VI it will be observed that the proportion of the monoamino acids present in the soil at the various times of sampling fluctuates. The lowest figure is 37 per cent. at the end of 86 days.

LYSINE NITROGEN.

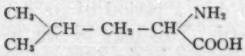
The analytical results show that lysine disappears from the soil quite rapidly. At the end of 44 days 89 per cent. of the lysine originally present in the proteins has been decomposed, and at the end of 86 days, 96 per cent. During the remaining and longer part of the decomposition period there is a continual gain in lysine nitrogen, indicating that synthetic processes are at work.

The gain in lysine nitrogen, after the original had practically vanished from the soil, is to be attributed to the action of the microörganisms in synthesizing some compound or compounds which give the analytical reactions for lysine. That this increase is due entirely to lysine cannot be stated, but lysine no doubt makes up a part of the gain observed.

It will be noted from Table VII that the two fractions which show the greatest amount of loss during the experiment are lysine nitrogen and monoamino acid nitrogen. It is not surprising that these two show the greatest loss when their chemical composition is considered. The monoamino acids are straight chain acids with the amino group in the alpha position to the carboxyl group. Lysine, a diamino acid, is also a straight chain acid containing two amino groups, one in the alpha position to the carboxyl group and one at the extreme end of the chain from the carboxyl group, or in the omega position. The relationship between lysine and the amino acids may be clearly shown by presenting the structural formulas for lysine and for leucine, for example:



Lysine.



Leucine.

However, it is observed that the lysine vanishes more quickly from the soil than the monoamino acids. This may be due to the fact that the omega amino group of the lysine exists free in the molecule of the native proteins which occur in the dried blood. Under such conditions this group is subject to deaminization by the action of the microörganisms before hydrolysis takes piace, while in the case of the monoamino acids hydrolysis must precede deaminization, since these acids are linked in the protein molecule in anhydride structure. Furthermore, if the omega group be split off from the lysine while it is still a constituent part of the protein molecule it is changed into an amino acid with but one amino group and would be determined analytically as monoamino acid nitrogen.

From Table VI it will be observed that there are very marked fluctuations in the proportions of lysine nitrogen in the soil at the end of each period. The lowest amount occurs in the soil at the end of 86 days, which was the low point for monoamino acids. The final amount is about half that originally present in the dried blood.

HISTIDINE NITROGEN.

At the end of 18 days the histidine nitrogen showed a gain. Although the compounds which cause this increase cannot be arrived at, it is possible that they are, in part at least, the purine and pyrimidine bases, which by the analytical methods would be classed as histidine nitrogen. It is well known that the protoplasm of microörganisms is made up of considerable amounts of nucleoproteins and nucleic acid, which on hydrolysis would yield the purines and pyrimidines.

At the end of 44 days 60 per cent. of the histidine nitrogen had disappeared; at the end of 86 days, 80 per cent.; and after 240 days, 83 per cent.

The proportion of the histidine nitrogen in the soil at the various times of sampling is about constant, with the exception of the 18-day sample.

ARGININE NITROGEN.

After 18 days 31 per cent. of the arginine had vanished from the soil, while at the end of 148 days 83 per cent. had gone. From the 148th to the 240th day, a period of 92 days, a gain in arginine nitrogen is observed. This may be due to nitrogen in the form of arginine, or nitrogen in the form of compounds

which give the analytical reactions for arginine. It is nitrogen formed by the action of microörganisms, probably a synthesis of protoplasm, and possibly in the form of proteins.

The relative amount of arginine nitrogen shows little fluctuation throughout the experiment and is a little greater at the end of the experiment.

AMIDE NITROGEN

The analysis of the figures for amide nitrogen brings out some interesting points. After 18 days there is an increase in amide nitrogen. It may be safely assumed that the compounds which this increase represents are acid amides, formed by the action of the microörganisms, existing in the soil either free or combined in the molecule of some new proteins contained in the protoplasm of the organisms. That there was actually an increase in this form of nitrogen after 18 days was, however, unexpected, since it is well known that microörganisms when grown in solutions of acid amides can use them for the building up of their protoplasm, and, furthermore, Jodidi (1912) has shown that acid amides are very easily and quickly ammonified when placed in an agricultural soil. It was therefore expected before the results were obtained that the amide nitrogen would be among the forms which would most quickly disappear from the soil. From Tables V and VII it will be observed that this fraction disappears least completely and most slowly.

The question arose as to whether the soil used was capable of ammonifying acid amides. Consequently one gram of pure asparagine, one of the two acid amides considered to be present in the protein molecule, was added to 100 grams of the air-dried Norfolk fine sandy loam to which no dried blood had been added. The soil was made to about a 10 per cent. moisture content and allowed to stand for four days. On analysis for ammonia it was found that the soil had converted 73.4 milligrams of asparagine nitrogen into ammonia nitrogen in this time, or, in other words, the soil in four days had ammonified 39.3 per cent. of the total asparagine nitrogen. This shows that if acid amides were free in the soil they would have been to a very large extent converted into ammonia during the 18 days of the experiment, and points unquestionably to the fact that the increase in this form of nitrogen is due to the synthetic action of the microörganisms in the building up of their own protoplasm.

(To be continued.)

Inclosed Arc-Lamp Market Vanishing. ANON. (*Electrical World*, vol. 68, No. 19, November 4, 1916.)—With the advent of the gas-filled incandescent lamp the future of the ordinary inclosed arc lamp has dwindled away. Ordinary tungsten lamps of the vacuum type had been competing with the inclosed arc lamp, but not with the degree of success that has attended the gas-filled unit. This new type of lamp has superseded the ordinary enclosed arc lamp for both street and factory lighting.

The new incandescent lamp has replaced the arc for a number of reasons. In the matter of annual cost and upkeep there has been considerable discussion, but it is now rather generally conceded that the gas-filled unit is more economical than the inclosed arc lamp. In the matter of outages and safety to trimmers the new lamp, of course, is superior. Furthermore, there are no carbons to deal with in incandescent lighting. Another reason, however, that has had no little share in popularizing the incandescent lamp is the development of ornamental lighting standards. The ornamental standard of both the single lamp and the cluster type has grown in popularity since the incandescent tungsten lamp was introduced. The luminous arc, however, has also become popular and is being used in large cities.

Moving-picture houses and theatres are now the largest purchasers of arc lamps, but there, too, the incandescent lamp is beginning to compete so that there seems every reason to believe that before long the inclosed arc lamp, as it is known, will be a thing of the past.

Well-Unit Water Supply. ANON. (*Engineering News*, vol. lxxvi, No. 24, December 14, 1916.)—For a number of years the city of Aurora, Ill., has obtained its water supply from a group of five wells. With the rapid increase of population in the past few years it became necessary to secure an increased supply. After investigation the city officials decided that instead of sinking more wells near the water-works it would be advisable to adopt the well-unit system. This consists of a number of deep wells distributed throughout the city, each operated by an independent pumping unit that delivers water directly into the mains. The wells are so located that the water pumped at each point has the shortest possible travel before being consumed, thus reducing to a minimum the friction loss in the mains. For this reason the wells are located usually near street intersections so that water can be pumped in four directions.

At present three of these new wells have been drilled. Their depth is approximately 2000 feet. A combination deep-well turbine and booster pump is used, directly connected to an alternating-current motor, the current for which is purchased. To increase the pressure in the mains for fire purposes the vertical deep-well unit will operate in series with a single-stage, double-suction, horizontal, motor-driven centrifugal pump. A pump efficiency of 70 per cent. has been realized.

THE PRODUCTION OF LIGHT BY ANIMALS.*

BY

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THE FIRE-FLIES OR LAMPYRIDÆ.

THE best known, most widely spread and altogether most classic object of study for animal luminosity is without doubt the "fire-fly" and its larval form the "glow-worm." It is not a "fly" nor is it a "worm," but belongs to the family Lampyridæ of the order Coleoptera commonly known as the beetles. A typical form is seen in Fig. 1, A and B.

It is a large group of many genera and hundreds of different species scattered all over the world, from the hottest tropical countries to the frozen swamps whose tops are thawed out in summer, at which time they support a good fauna and flora.

As is natural, the form and habits of so large and widely distributed a group are subject to many variations and some of the species show no light at all on their bodies, while others glow from many parts of the body where light organs are formed. Several species can be found living in the same terrain in almost any region of the world.

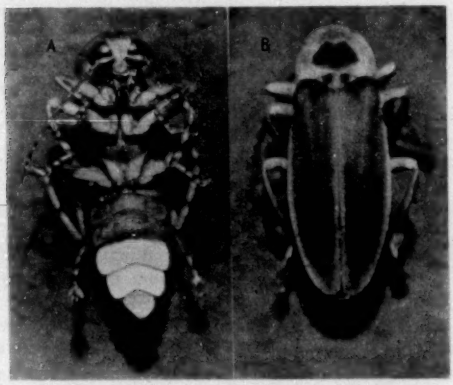
In general form and appearance and in size these beetles show but little variation. It may be said that nearly all of them are from six to twelve millimetres in length and that the adults are of a moderately elongate form. The head is wholly or partly covered by a projecting and gracefully curved overhanging edge of the thoracic integument (see Fig. 1) and the antennæ are long and slender.

In color they are dark, usually black or brown that may be striped longitudinally with gray or white. At the anterior edge of the thorax a certain amount of dull yellow marked with red is usually present. Some have a uniform silvery gray as the body color, while a few are marked or mottled with white. Fig. 2 shows several varieties.

* Continued from page 220, vol. 183, February, 1917.

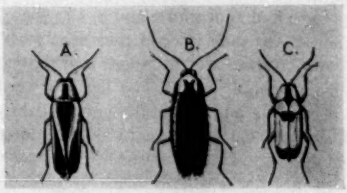
The larvæ are usually more elongate, are plainly segmented and crawl on the ground, this giving them the name of "glow-worm" (see Fig. 3). The back is dark and the head retractile

FIG. 1.



Photograph of dorsal (B) and ventral (A) views of an alcohol specimen of *Photuris pennsylvanica* male.

FIG. 2.



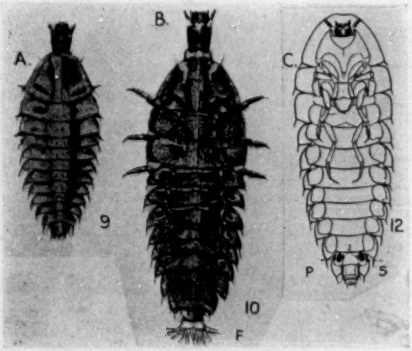
Figures of three exotic lampyrids (fire-flies). A, *Photuris transversa*. B, *Photuris villosa*. C, *Photuris alternans*. (From Henneguy.)

into a cavity in the thorax. These larvæ live in dark, damp localities in swamps or on the edges of woods and thickets, crawling over the ground or on leaves and grass (see Fig. 4). They are carnivorous, eating only snails and slugs, and are nocturnal

in their activities. During the day they sleep under dead leaves. In the more northern climates they hibernate during winter in mould, or under logs, or in the ground.

When about to pupate the larvæ of most of the species build a cell on the surface of the ground under dead leaves and change their skin to become the cream-colored pupæ which cannot walk but lie inert for a week or more until the skins are cast to produce the adult insects. Fig. 5 shows the pupa of one species. In some tropical forms the pupæ are attached to the side of a tree some little distance above the ground.

FIG. 3.



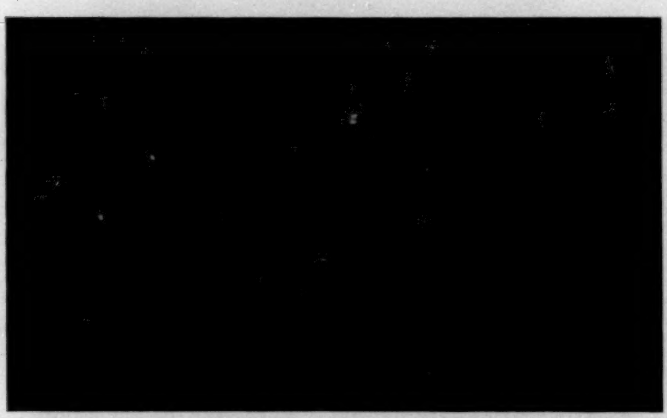
The larva of *Photuris pennsylvanica*. A, first instar at time of hatching. B, adult; not magnified as much as A. C, adult, ventral view, showing the positions of the larval light organs (p). (After F. X. Williams.)

The adult insect emerges in late spring or early summer in colder latitudes or in the wet season in tropical countries. After hatching and drying its skin, it moves about to seek its mate and when the female is fertilized she lays her eggs, in early or middle summer in New Jersey. These eggs are laid in mould around the roots of grasses and they take some time to hatch. When the young larvæ emerge they look much the same in form and color as the older ones and are ready almost at once to begin eating snails. This process is very interesting and will be dealt with on a following page.

After growing all summer and fall the animal hibernates. It is late in the fall before it goes into winter quarters and a warm spell in winter may bring it out for a few days at any time. It emerges in spring in March or April and passes the summer eating and growing. Wet weather is favorable, but very dry weather prevents it from moving about or catching snails which also seal up their opercular valve and hibernate when it is very dry.

A second winter is usually passed in the larval state and upon emerging from this rest the animal stores fat and goes into the

FIG. 4.



Larvæ of *Pholinus sp.* (probably *consanguineus*) in their habitat at dusk. Drawing from nature by Bruce Horsfall.

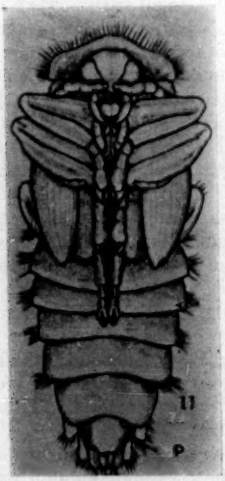
pupal stage about May 15th–20th, building its little cell on the surface of the ground and under leaves or mould. The cell is built with a mixture of clay and saliva and is made of strands of this material that somewhat resemble very thin earthworm casts. Only a lattice-like cover is built, the ground being scooped out to form the lower wall. In this cavity it lies inert on its side and partly curled up. Its tissues appear swollen between the segments and assume a dull whitish color.

In a short time the skin is cast and the light-colored pupa

is revealed. Its powers of movement are extremely limited. About eight days is the time that elapses before it again changes its skin and the adult insect crawls out.

The question of the food and the manner of feeding of the larvæ of Lampyridæ has been carefully studied and described by Newport, Henri Fabre and R. Vogel. It appears that during its entire life, from its first hours after hatching until it is ready to

FIG. 5.



Pupa of *Photuris pennsylvanica*. The larval light organs still persist at P. (After F. X. Williams.)

pupate, the larva of *Lampyris noctiluca* feeds on nothing but pulmonate mollusks, both the naked kinds, such as *Limax* and *Arion*, and the forms that possess a shell, as *Helix* and its allies.

Its method of securing this food is essentially the same at all times, varying only slightly and in a quantitative way according to the relative sizes of the larva and its prey and the condition of strength and hunger of the larva. The larva cautiously approaches the snail or slug with extended head and widely opened

jaws. Seizing a favorable moment, it quickly bites its prey as near the head as possible and then moves back. The bite is repeated, sometimes for as many as twenty times. The snail soon shows signs of distress and in one or two hours, or sooner, becomes torpid as though narcotized. Its heart beats slower and breathing slows down and stops. After a short time it dies.

This would indicate that it had been poisoned by the bite. Experiments tend to show that this is true. It requires many bites by a small larva to overpower a large snail, and few bites for a large larva to kill a small snail. Also, if a larva is allowed to bite several snails without feeding on them and is then given a fresh one it does not readily overcome it by many bites, although its first victim is soon dead from its single attack.

Further, a brownish fluid from the midgut is seen to come from the mouth of irritated larva, as well as to be ejected when biting the snails. This fluid when dried on the slide shows a hard drop that clings to the glass and cracks with the drying as egg albumen would. Also, when stained it takes eosin intensively in the same way, and other tests also indicate that it is a proteid. Sections of the midgut show this material as granules that come from the cells, so that we may look upon it as a proteid poison.

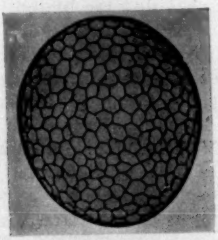
When the prey is dead the larva begins to feed upon it. It does this by chewing the flesh with its rough mandibles and ejecting more of the brown fluid. Under the influence of the chewing, and particularly of the fluid, the flesh turns brownish and dissolves into a structureless brown broth that contains no fragments of cell or nuclear material. This fluid is then sucked into the digestive tract.

The larva becomes gorged with this material and after hours of feasting retires in a sleepy condition to further digest and assimilate this food. So full is it that its former flat shape is now rounded. What is true of this form in regard to its feeding is probably true of most of the other Lampyrids. Possibly we may find some other kinds that attack other prey, as earthworms, for instance. Vogel found that starving larvæ would chew and digest small bits of veal, which was dissolved in the same way as snail flesh under the influence of the brown fluid.

POSITION AND NUMBER OF LIGHT ORGANS.

The lights vary in number and somewhat in position in the various species. In the first place, this power is already seen in the earliest moments of the creature's life, in the egg. This single cell sheds a pale glow when first laid in the few forms where it has been possible to study it. This is true of the egg even before laying it in mother's body. When laid it is of a light pinkish or yellowish hue and its surface is marked by tiny facets (see Fig. 6). It must be seen in complete darkness to have the glow apparent. This weak light comes from the entire peripheral cytoplasm and by some it is thought that it originates

FIG. 6.



Egg of *Photuris pennsylvanica*. The facets correspond with the yolk granules inside. (After F. X. Williams.)

in the yolk material. It is more probable that it comes from tiny granules of photogenin in the cytoplasm between the larger yolk granules.

No further observations have been made on the light until the embryo is well developed and is almost ready to hatch. Then the light is seen to come from two distinct points and these points are readily recognizable as the typical light organs of the larva as seen in all forms without exception.

These organs are two latero-ventral, rounded spots on the eighth abdominal segment. They are applied closely to the hypodermis which covers them and bulge outward as two knobs or sometimes two weaker lens-shaped prominences. Fig. 4 shows their position. The light organs of the larva never flash or sparkle, but, when in action, shine with a steady glow. Much

of the time no light at all comes from them and they do not glow when the larva is resting or hibernating beneath the dead leaves on the ground.

The light is brought into action whenever the animal is disturbed or roughly handled. Then the glow slowly appears, and attains its maximum in a few seconds. It will continue as long as the stimulus is applied and afterward it gets weaker and weaker until, in a minute or more, it has entirely disappeared.

On a damp night, when the creatures are out hunting their prey, they have the habit of turning the light on and allowing it to glow for considerable periods, for minutes at a time. Then, for no known reason, the light will die out, to reappear again later. This is particularly true of large larvæ in the grass, late in the fall on cool nights, when they can be seen for several hundred feet away.

The larvæ usually occupy well-defined areas or colonies where the adults, later, will fly during the mating season. They can best be seen and caught on dark nights after or during a drizzling rain.

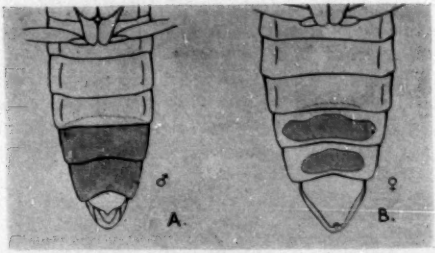
The larva keeps its light, up to and during the torpid condition that occurs after it has built the nest in which it pupates. Even when in this helpless condition it responds to handling or shaking by turning on its lights. After the skin is shed and it has become a pupa these two larval lights still shine until shortly after the time when the adult light is developed. They then disintegrate and disappear in most of the species, although retained in some.

The adult light organs appear during the pupal condition, first as patches of lighter integument, later as white areas that can shine. They do not light all over the surface of these areas at once, but show streaks of light and smaller patches, usually near the middle or posterior edge. Just before hatching they light up all over but do not flash, slowly lighting and slowly darkening, much as the larval organs do.

These adult organs show considerable variation both in number and in the different species; also some difference in the two sexes of a number of the species. The commonest and most ample arrangement appears to be an organ covering most of or the entire ventral surfaces of the sixth and seventh abdominal segments, as seen in the male of *Photuris pennsylvanica* (see Fig.

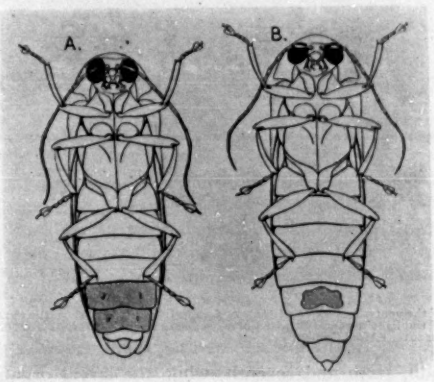
7, A). In fact, this consists of two organs, one occupying each of these two segments. In the female the organ is usually found

FIG. 7.



Sketch of the ventral aspect of the abdomen of the male (A) and female (B) of *Photuris pennsylvanica* to show position and size of light organs. The stippled areas represent the light organs. (After F. X. Williams.)

FIG. 8.



Sketch of the ventral aspect of *Pholinus consanguineus* to show position and size of light organs. A, male. B, female. The stippled areas represent the light organs. (After Watase.)

to be in a similar position but restricted to a more or less smaller and central portion of the two segments. This is shown in the female of *Photuris pennsylvanica* (see Fig. 7, B). In some other

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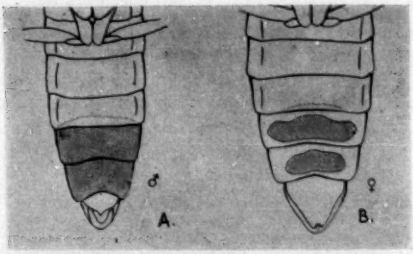
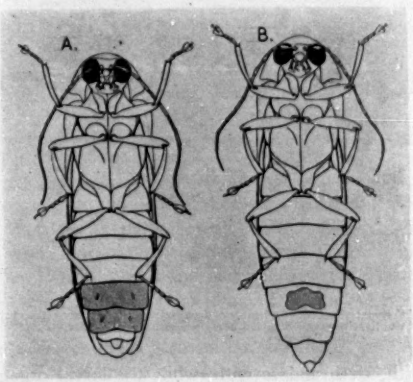


Sketch of the ventral aspect of the abdomen of the male (A) and female (B) of *Photuris pennsylvanica* to show position and size of light organs. The stippled areas represent the light organs. (After F. X. Williams.)

FIG. 8.



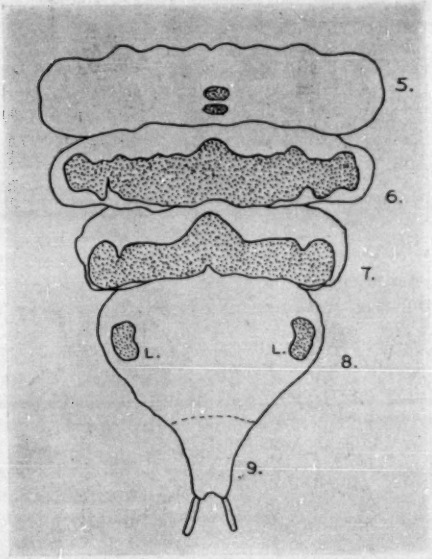
Sketch of the ventral aspect of *Pholinus consanguineus* to show position and size of light organs. A, male. B, female. The stippled areas represent the light organs. (After Watase.)

to be in a similar position but restricted to a more or less smaller and central portion of the two segments. This is shown in the female of *Photuris pennsylvanica* (see Fig. 7, B). In some other

species the female has the organ on but one of these segments, when it is the most anterior of the two, or the sixth. We can see this in the female of *Photinus consanguineus* in Fig. 8, B.

In certain forms the female has median light organs on more than two segments, as in *Lampyris noctiluca,* where they appear

FIG. 9.

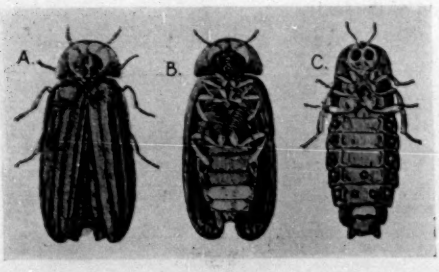


Sketch of the ventral aspect of a female of *Lampyris noctiluca* to show the number, position and extent of the light organs. Stippled areas represent light organs. L, larval light organs on eighth segment. (After Geipel.)

on the fifth, sixth and seventh, while the larval organs persist on the eighth (see Fig. 9). A still more extensive development appears in *Lampyris splendidula,* where the male has large median organs on the sixth and seventh (Fig. 10, B), while the female shows one small median organ on the fourth or fifth (with some variation), two small lateral organs on the sixth, one large median

organ on the seventh and five medium-sized light organs on each edge of the abdomen on the second, third, fourth, fifth and sixth (Fig. 10, C). This female is half-winged or almost wingless, white or light cream-colored in hue, and lies prone on the ground, shining brightly, much brighter than most other forms, while waiting for her mate. The light is constant like the glow-worm's (larvæ) and does not come in flashes as in most adult forms. The writer has collected many of these illuminated females on the edges of forests on the mountain side near Neustadt a/d Hardt, in Southern Germany.

FIG. 10.



Three views of the fire-fly, *Lampyris splendidula*. A, dorsal view of male. B, ventral view of male. C, ventral view of female to show the numerous and widely distributed light organs. (After Flöricke from Mangold.)

A general survey of the question of the position of light organs in the Lampyridæ shows that they vary greatly in number and position, and yet certain general principles can be laid down which seem to govern their arrangement. The first idea is that they incline to be placed on the posterior portion of the abdomen and that they are ventral in position. This accords with the general law that practically all luminous organs in the various groups of animals are ventral in position and show their light downward.

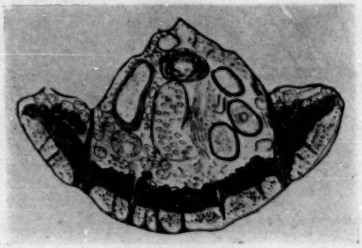
The next apparent rule is that the lights are bilateral in their more primitive manifestation, as in the larvæ, and in those cases when they are found in larger numbers, especially in the cephalic direction. The median lights must all be looked upon as a fusion of bilateral pairs and as a more specialized condition of the organs. Thus, the extreme caudal organs in adult fire-flies are

usually larger and fused into such a single median mass, while in those that appear cephalad of the sixth and seventh segments they are almost always smaller and widely separated on the lateral sides of the segment. This holds true in all Lampyrids as well as in the allied *Phengodes*.

STRUCTURE OF THE ORGANS.

All the organs, both larval and adult, agree in some general features. They each consist of two fleshy layers of cells attached to the integument (hypodermis and cuticle), which becomes, over the area involved, perfectly transparent, thus permitting the color of the layers to be seen. Fig. 11 shows these two layers in a section of the body.

FIG. 11.



Low-power view of a transverse section of the body of an adult fire-fly through the light organ. (After Townsend.)

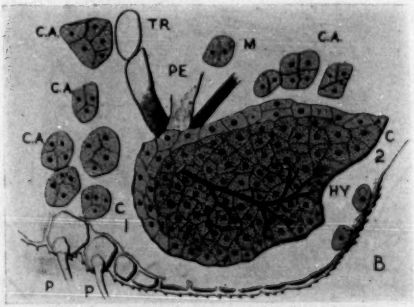
The layer next to the integument, commonly the ventral layer, since the organ is usually on the ventral surface, is the layer of light cells and it is a transparent yellow in color. A pale yellow color appears to be typical of most protoplasm, but a somewhat richer yellow also appears to be characteristic of photogenin in the few cases in which we have been able to see it, either in isolation as in *Cypridina* and *Cavernularia*, or still mixed with the nuclei and cytoplasm of its parent cells as in some squids, certain fishes and the fire-fly.

The second layer is further inside and is therefore dorsal in position to the first. It approximates the light layer in thickness and is composed of cells of nearly the same size. These cells, as

in *Pyrophorus* (see Chapter 10), contain in their cytoplasm a mass of granules of calcium urate and their bodies act as a reflector of light, thus performing two duties: they prevent the light that is generated in the light cells from being thrown into the delicate internal tissues of the body and they also throw back these light rays that start dorsally or inward and add them to the rays that have started outward, thus nearly doubling the illuminating powers of the organ.

When we come to study the structure in further detail we find that certain differences, of degree mostly, make it desirable to

FIG. 12.



Low-power view of part of a transverse section through the body of a larva of *Lampyris noctiluca* to show a section of the larval light organ. The ventral mass of darker cells with a trachea branching among them are the light cells. The lighter, thinner mass of light-colored cells are the reflector cells. (After Henneguy.)

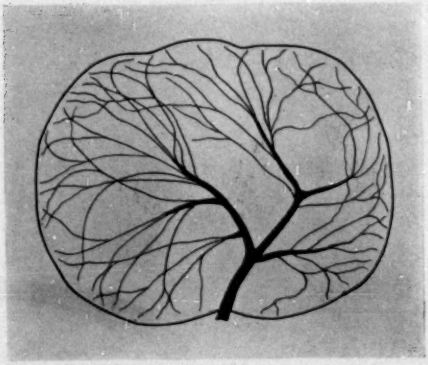
examine the organs of the larva first. Fig. 12 is a representation of part of a transverse section through the eighth abdominal segment of a larva of *Lampyris noctiluca* and shows this organ *in situ*. Here it can be seen that the light cells or ventral layer form a thick rounded mass and are, in nature, almost in contact with the hypodermis and cuticle. In the figure they are some distance from it, due probably to osmotic action of the fixing and embedding processes. These light cells are packed closely together in the mass and show no morphological arrangement other than the rounded shape of the mass.

Each cell is robust with a large nucleus and large cytoplasmic

body which would not be so large and dense if it were not active in some secretory process. The granules that fill it are proof of such an activity and they are granules of photogenin, small rounded granules that fill the cytoplasm in all parts. No portion is free from them.

We see no evidence of a blood supply, although one may be present. Or the cells may pass the necessary substances from one to the other. As to the air supply, it can easily be seen in the figure that this is abundant and consists of tracheal twigs,

FIG. 13.



Drawing of a single larval light organ of *Lampyris noctiluca*, treated with caustic potash to render the tissues transparent and bring out the tracheal system, here seen black. (After Geipel.)

as represented by a single branching twig in this case. It arises, out of the section, from one of the larger branches such as is shown above the organ in the figure.

The structure of the terminal parts of this branching twig has been carefully studied in the adult by Bongardt, Geipel, Emery, Lund, Vogel, Shultze, Townsend and many others. Its appearance in the *larval* organ has best been demonstrated by Bongardt. In Fig. 12 Henneguy shows a single trachea entering the organ and branching in the light-cell mass. Fig. 13, from Bongardt, shows a preparation made transparent by caustic potash and showing the finer branches of this single trachea which sup-

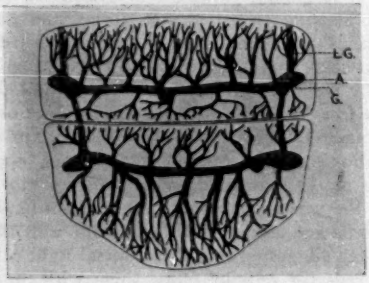
plies the layer. Tracheal end-cells seem to be wanting in this larval organ.

Outside of and dorsal to the light-cell mass are seen the layer of dorsal reflector cells. This layer is thin in the larval organ and yet it forms a complete and efficient reflector. The individual cells will not be described because they are apparently exactly like the reflector cells as seen in the adult.

THE LIGHT ORGANS AS FOUND IN THE ADULT.

The adult light organ is not the same as, nor is it directly derived from, the larval organ. Its relations and method of development will be discussed in some following pages devoted to the subject.

FIG. 14.



View from ventral side of a diagram of the arrangement of tracheæ that supply the two light organs in the male of *Luciola africana*. (After Geipel.)

As has been said, it consists of one or more areas on the ventral side of the abdomen, usually two large portions of the sixth and seventh segments. Thus it is multiple, but all of the portions are alike in structure, consisting of ventral light-cell layer and a dorsal reflector layer. Fig. 11 shows these layers in a section of the body of the adult insect.

The organ has a very large air supply coming from specialized tracheæ that are found in the tissues immediately above it. Geipel shows that in *Luciola africana*, a main trunk (A), formed by the anastomosis of the trachea from each side of the segment, forms the basis of this supply in each segment and that the air is con-

ducted down to the organ from this large tube by about fifteen side branches (Fig. 14), which in turn divide into the unit trachea of the organs.

The reflector layer is composed of a solid mass of large cells that resemble greatly those of *Pyrophorus*. They have a nucleus typical of the insect and a large cytoplasmic body in which are secreted and stored a great mass of bodies of calcium urate which completely fills the cell outside of the nucleus. Geipel has compared the size of nucleus and cell in this layer with the cells of the underlying light layer in some African Lampyrids and finds that, while the light cells in these Lampyrids average 0.0304 mm. in diameter and the reflector cells 0.0272 mm., which is a small difference, the nuclei of the light cells average 0.0064 mm. and those of the reflector cells 0.0112.

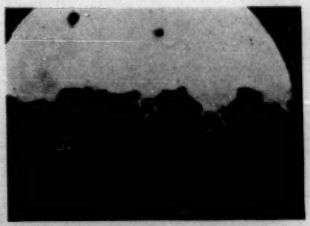
The writer has made similar comparisons in several North American forms and two Japanese forms and has noted the figures of several species in papers by Lund, Bongardt and others, and finds that such large differences do not exist in these forms. In general the nuclei are much alike in size and form in both layers. This form is sometimes round, but more often they are irregularly rounded or even lobed and with blunt processes.

The question has been raised by Lund and others as to the origin of the urates that are found in the reflector cells. Is it possible that the waste products of metabolism in the light cells and muscle cells are used to fill these units with this material? Some have even suggested that these dorsal light cells are transformed into reflector cells by filling them with the urates from the light processes in the cells below them and that the animal begins life with a thin reflector layer and a thick light layer and that as the light is used and the creature grows older the reflector layer thus grows thicker at the expense of the light layer. Most of them have answered this in the negative for two reasons: First, the two layers remain about constant in their relative sizes at all ages. This relation is about half and half in *Luciola parva* and *Luciola vitticollis* from Japan. The same holds true for *Photinus marginellatus* and in *Photuris pennsylvanica*. In some others, however, as the fire-flies from Africa, Italy and Northern Europe, Geipel found that the reflector layer occupied one-third of the thickness of the organ and the light layer two-thirds. In one case, a section drawn by Townsend from an un-

named species shows the reflector layer thicker than the ventral layer.

The second reason for deciding that the dorsal or reflector layer does not grow at the expense of the ventral or light layer is that no cells have ever been observed in any stages of transition. Such a transformation would be easily discernible, as the cells of each layer stain in very markedly different ways. To sum up, it is probable that the reflector cells have the specific power of secreting the urates and maintaining them in their cytoplasm in a form well adapted for reflecting light; also, that they possess this power from the very first and that no cells from other tissues are ever added to this layer. Fig. 14 is a photograph of the

FIG. 15.



Photograph of the transversely cut end of the seventh abdominal segment of *Photuris pennsylvanica*. Light areas represent urates in reflector shining by the light of a bull's-eye lantern placed behind the camera. (After Lund.)

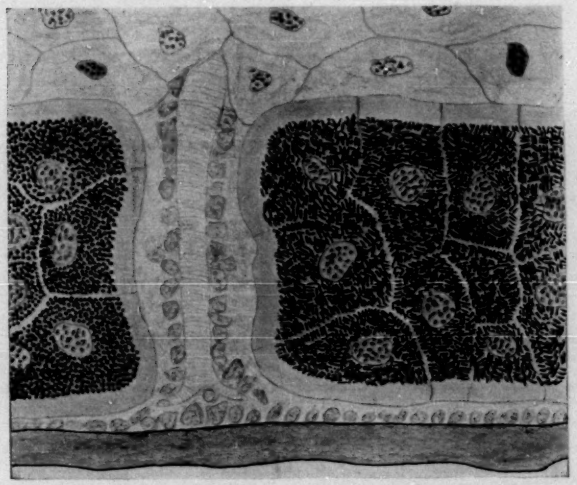
fresh-cut body of *Photuris pennsylvanica*, showing the deposits of urates by reflected light. It can be seen that they are not confined to the reflector cells alone but are also found in small quantities in the luminous cell edges, around the nuclei and in some of the visceral tissues.

The reflector cells form a compact mass, but tracheæ as well as nerves are found branching among them. The nerves probably go on through to supply some of the light tissues, and most of the trachæ do the same. But some small tracheal branches end in the reflector layer, and this ending is by means of the much-discussed "end-cells."

Passing now to the ventral layer or light-cell layer, we find that it is made up mostly of these light cells. Each cell is provided with a large nucleus as described, and its large cytoplasmic

body is filled with the secreted photogenin or luciferine. This material appears in the form of granules which are small but of a definite shape. In *Photinus marginellus*, for instance, they appear as small round bodies in the male. But in the female they are elongate bodies of larger size. In the first they closely resemble cocci and in the second rod-shaped forms like bacteria.

FIG. 16.



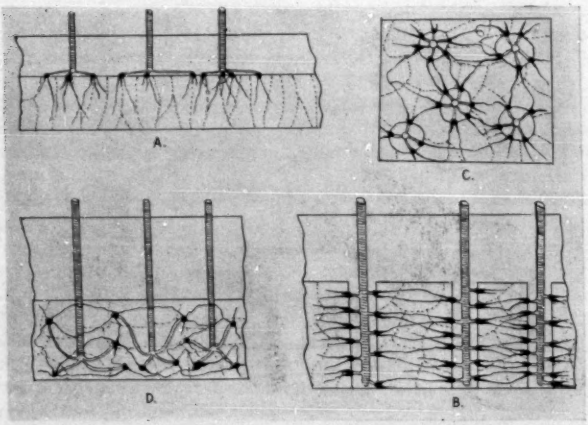
Part of a vertical section through a light organ of *Photinus marginellus*, showing one cylinder with its tracheal unit and accompanying tissues poorly stained; also, at top, parts of nine reflector cells, also poorly stained. This figure is intended to show to best advantage the light cells, two masses of which appear. In the mass to the right the female type of photogenin granules is depicted. In the mass of light cells to the left the male type appears. The oxygen protecting membrane or ectosarc of the light cells is well shown. (Original drawing.)

In fact, they were taken to be bacteria by Pierantoni, who ascribed the light of fire-flies to bacteria living symbotically in the tissues of the light organ and even thought that he could cultivate them on artificial media. His cultures must have become inoculated by outside bacteria from air, water or other sources.

The staining of the photogenin granules was a matter of guesswork for some time to the writer. They are very hard

to stain in ordinary fixations, coming out untinged in many good stains. Osmic acid only slightly stains them. Finally it was discovered that all that was necessary was to see that the fixative was heated nearly to the boiling point, no matter what fixative was used. At least this was true of Flemming's fluid, Bouin's fluid and corrosive sublimate and acetic acid. Then iron hæmatoxylin brought them out clean and blue-black on a light ground. Fig. 16 shows them in male and female in *Photinus marginellus*.

FIG. 17.



Four diagrams to illustrate the three known types of fire-fly light organs. For explanation see text.

In some of the fire-flies (*Photinus marginellus*) the granules of photogenin do not fill the entire cytoplasmic body. In this case, as is shown in Fig. 16, there is a peripheral zone which is free from them. This zone does not exist where one light cell touches another. Lund figures and describes this zone but is at a loss to account for its function. He saw that it was dense and stained differently from the rest of the cytoplasm.

In the writer's opinion this membrane-like zone, common to the entire exterior of any mass of the light cells but not existing where their surfaces touch each other, is a defence against the

entrance of any oxygen that might come into the cells except through the tracheal capillaries. What may happen, one may ask, in the forms where such a membrane does not appear? Its place may be taken in these cases by a thinner layer or a better general resistance of the cytoplasm or the cell membrane to the access of oxygen.

The arrangement of these light cells in the various forms, while seemingly different in many of the species, has a common plan

FIG. 18.

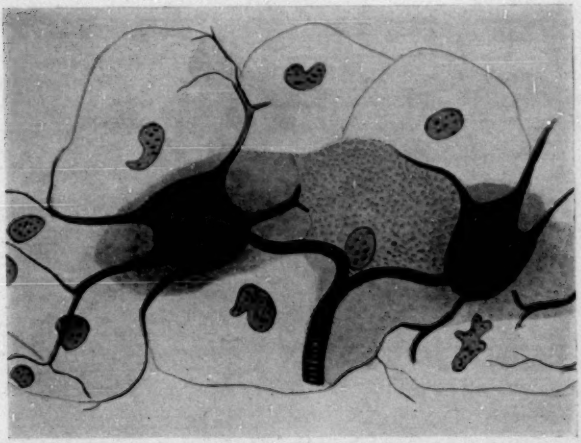


Figure of a portion of light tissue from *Lampyris splendidula* to show effect of breathing osmium vapor on the cytoplasm of the end-cells and surrounding tissues. (After Bongardt.)

with reference to their access to the supply of tubes bearing the oxygen. In some forms of *Photuris* the cells form what is practically a single layer. In this case the unit branches of tracheal supply come down through the reflector layer at well distributed points and branch out into tracheal twigs that spread in several directions over the upper surface of the light layer and terminate in tracheal end-cells, from which the tracheal capillaries branch and penetrate the mass of light cells. Fig. 17, A, is a diagram illustrating this relation.

The second type of adult Lampyrid organ is where the light layer is composed of several thicknesses of cells. In this type we find two subtypes. First comes the condition found in our American species of *Photuris* and *Photinus*. Here the tracheal unit branches enter the light layer through a well or circular hole in the mass of light cells. The trachea and its accompanying tracheal epithelium and tracheal end-cells fill this well from top to bottom and form a mass of tissue called from its shape "the cylinder." These cylinders are spaced through the layer in such a way that the air supply is kept within a certain distance of all light cells. Fig. 17, B, will show a diagram of this arrangement seen in vertical section, while C in the same figure will show a diagram of the arrangement as seen in a horizontal section cutting across the cylinders.

This arrangement is like the first type (A) in that the tracheal units do not actually enter the light cells and that the tracheal end-cells rest on the surface of the light-cell mass either on its actual upper surface between the cylinders or on the inner side of the cylinders. Thus, in regard to its actual physiological opportunities, it is in reality only an amplification of the first type. On the other hand, the tracheal units do actually leave the reflector layer when they pass down into the cylinders.

The second subtype of this group is found in several far eastern forms and can be well seen in *Luciola parva* and *Luciola vitticollis* from Japan. In this kind the light-cell mass is not amplified by the invaginated cylinders, but forms a smooth, compact mass of several layers of cells in depth. The tracheal units come down through the reflector layer and enter the light-cell layer without any accompanying invagination of that layer into "cylinders." The units, after penetrating half way, more or less, branch into the terminal twigs and these scatter about for a short distance and terminate in the end-cells, from which they branch out into tracheal capillaries. Fig. 17, D, shows a diagram of this condition.

AIR SUPPLY.

We have seen that, since the oxygen supply of insects is not carried by the blood, but by a system of air tubes, the various tissues of insects are dependent for their air with its supply of oxygen upon a system of branching of these tubes called the

trachea. As has already been shown (Fig. 14), each adult light organ in the fire-flies is supplied by two large tracheal trunks that meet and anastomose from the two sides of the segment and give off in their length about fifteen secondary branches that we have called the "tracheal units."

These tracheal units then approach the light-cell mass and either deploy on its upper surface or enter the cylinders or pass directly into and between its cells. Finally they give off a large number of "terminal twigs," each of which terminates in an "end-cell." Up to this point all the tracheal channels, trunks, tracheal units and terminal twigs are of the same structure. They are formed by a membrane composed of the tracheal epithelial cells, which are an invaginated contamination of the external hypodermal cells, and the actual wall of the circular tracheal channel is a continuation of the external cuticle, much reduced in thickness. Owing to this thinness and necessary delicacy, the wall of the tracheal channel has to be reinforced by a series of circular or spiral ridges called the tænidia. At the distal tip of each terminal twig one of the cells of the tracheal epithelium becomes much enlarged and its distal end is prolonged into several (2 to 7 or more) fine protoplasmic branches which become more slender as they reach out and branch between or through the tissue cells that are to be supplied with air. This cell and its branches then continue the formation of cuticle in the form of fine tracheal capillaries or tracheoles that extend out in the distal arms of the end-cell as far as they continue. Such end-cells are found in most other insect tissues as well as in light tissues.

It is in and through these tracheal capillaries or tracheoles that the physiological exchanges of the light cells take place. This has been abundantly proved by the experiments of Emery, Wieliwiejski, Bongardt, Lund, Geipel and others. This proof consists in forcing the living insect to breathe the strong vapor of osmic acid and then noting, in subsequent preparations, where air bearing this osmic vapor has passed most freely through the tracheal channels and stained the surrounding cells.

The results have shown that, while some osmic vapor has gotten through the larger channels, the greatest effect takes place in the distal part of the end-cells and in the tracheal capillaries. Fig. 18 shows this abundantly.

Another question is, as to whether the tracheal capillaries

anastomose or not with the capillaries from other unit trachea. These capillaries are very fine and hard to follow, but the weight of evidence seems to show that some if not all of them do. Town-

FIG. 19.

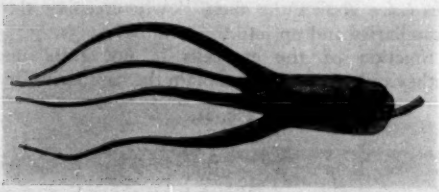
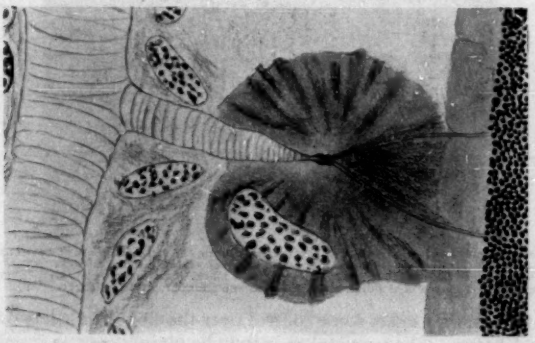


Figure of a tracheal end-cell from *Photinus marginellatus*. (After Geipel.) This figure shows the nucleus terminal twig and capillaries, but does not show all the cytoplasm of the cell. This latter forms a larger and more rounded body in addition to the mass seen here. It also has a radial arrangement of its protoplasm.

FIG. 20.



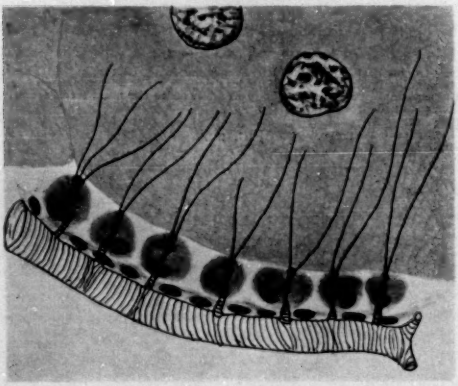
View of a tracheal end-cell from *Photinus marginellus*. Fixed in hot Bouin's fluid. Tracheal unit is seen giving off a terminal twig, which terminates in the end-cell. Origin of two capillaries is seen, also radial arrangement of cytoplasm (probably muscular). The denser mass of cytoplasm between the tracheoles and against the light cell is probably the secondary mass that is stained black in the next section. (Original drawing.)

send figures this anastomosis, and, as Lund says, such an anastomosis might contribute to the flow of air through the capillaries. This would be especially true if the air pressure was slightly different in two tracheal units whose capillaries were in connection.

Another interesting question is whether the capillaries are filled with air or body fluid during life. The probabilities are that they do contain air but that upon the least injury, mechanical or pathological, the body fluids invade their lumen and slowly fill the first and then fill the terminal twigs. Quick dissections of the tissues have shown the fluid slowly creeping through the tracheal capillaries and up into the terminal twigs.

The function of the end-cells is not fully understood. Whether they only form and maintain the capillaries or whether,

FIG. 21.

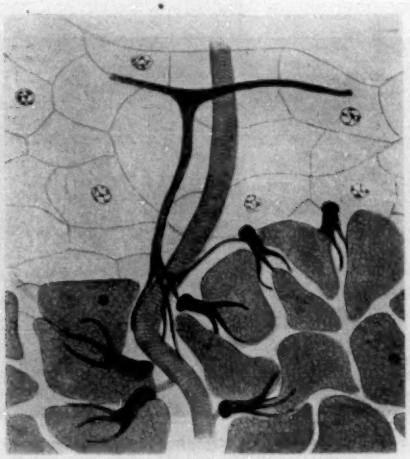


Seven tracheal end-cells with their tracheoles entering the light-cell mass of *Flectens marginellus*. With this fixation and stain all nuclei and much chiten is stained black. Also a distal secondary mass of tissue around the tracheoles stains black. The photogenin granules show no trace of stain. Fixed in cold sublimate-acetic acid and stained with iron hematoxylin.

in addition, they exert some control over the flow of air has often been debated. The terminal twig may be plainly seen as it enters the end-cell (Figs. 19, 20, and 21). Inside this cell the large round nucleus is visible, usually to one side, and about in the middle the twig suddenly loses its tænidia and shows a strong, dark-staining sheath that forms a distinct body (see same figures). This body is smaller than the twig in some forms and slightly larger in others. It ends in a point in either case, and from this point the tracheal capillaries, or "tracheoles," as they are called by some,

are given forth. This specialized body forming the end of the terminal twig inside the cell is not readily seen in osmic preparations on account of the darkening of the surrounding cytoplasm; but in sublimate preparations stained with osmic acid it becomes visible, and it stains darker than the other portions of the larger tracheal channels. Sometimes it also stains darker than the capillaries that it gives off (Fig. 21).

FIG. 22.



Showing six end-cells in the light tissue of *Pholcus marginellatus* from South America. A tracheal unit sends off air supply to the light cells through the terminal twigs and tracheal end-cells; while a nerve stem sends fine nerves to the end-cells for their control. (After Geipel.)

This standing reaction may point to a contractile layer of cytoplasm surrounding it, with the possibility of a valve, in addition, in its lumen. Also the larger body of cytoplasm surrounding it sometimes shows a radial structure that may point to a general contractile power (Fig. 20). Further evidence that this cell in some way controls the passage of air into the tracheoles is shown by the fact that the nerve supply sends a minute fibre to each of these end-cells. Geipel shows this, although he does not show the definite nerve ending on each cell (Fig. 23).

Such a control of the air supply by the end-cell with its muscular power and an adequate nerve supply would account for the control of the flash of light of the fire-fly. This light is emitted in short, sharp flashes, although sometimes, when injured, fatigued, or excited, or subjected to chemicals or near death, it also shows a steady glow. It has been shown by experiment that the light is controlled by the nervous system in *Pyrophorus* and the necessary nerve supply exists for this control in the Lampyrids.

FIG. 23.

View of fire-flies, *Photuris* and *Pholinus*, during their evening flight in early summer. (Drawing by Bruce Horsfall.)

The control of the light has even been shown indirectly in these latter forms. It must have a reflex centre in connection with the sex centres, and the glow in injury and other unusual conditions show that its control is probably of an inhibitory nature, with the end-cells as the seat of the direct action.

A following chapter will deal with the development and larval transformation of the light organs of Lampyrids and the physiology of the processes in these forms.

(To be continued.)

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A SPECIFIC GRAVITY BALANCE FOR GASES.[1]

By Junius David Edwards.

[ABSTRACT.]

THE need for an accurate method of determining gas densities has been especially urgent in the natural gas industry where the measurement of gas by means of orifice meters requires a knowledge of the density of the gas. An investigation by this Bureau of the effusion type of apparatus, which has been generally used for this purpose, but which has proven unreliable in practice, has shown the need of more precise methods. To supply this need the present method was adopted and suitable apparatus designed.

The principle of the method employed is based upon the laws of the compressibility (Boyle's law) and the buoyant effect of gas. The balance contains a beam which carries on one end a relatively large globe and on the other a small counterweight; the beam is enclosed in a gas tight chamber. The buoyant force exerted upon the globe is proportional to the density of the gas and therefore to its pressure. Therefore, if the buoyant force exerted upon the globe is made the same as shown by its position of equilibrium when it is suspended successively in two different gases, then the densities of the two gases must be the same at these pressures, or the specific gravity is the inverse ratio of the pressures.

In operation the balance case is filled with air and the pressure adjusted until the beam balances. It is then filled with gas and the pressure required to secure a balance is determined in the same way.

The apparatus described provides a quick, accurate means of determining gas density. The balance beam is supported on two needle points which give high sensibility. The needles are easily adjustable and in contrast with the metal or quartz knife edge usually used, can be obtained almost anywhere, are inexpensive,

* Communicated by the Director.

[1] Technologic Paper No. 89.

and can be replaced as often as necessary. The success obtained in the use of this apparatus is mainly due to the high sensibility afforded by this means of support. It is necessary to remove the beam from the case only when it is desired to transport it. No levelling bottle is necessary in adjusting the gas pressure within the balance, this being accomplished by means of a needle valve which affords precise control. A portable outfit is described which combines lightness of weight, convenience in use, and durability without any great sacrifice of accuracy. No preliminary calibration of the apparatus is necessary. The results obtained with this balance were compared with those obtained by a direct weighing method and it was shown that an accuracy of 1 or 2 parts per 1000 could be obtained quickly and without elaborate precautions.

THE STRUCTURE OF THE COATING ON TINNED SHEET COPPER IN RELATION TO A CURIOUS CASE OF CORROSION OF THIS MATERIAL.*

By Paul D. Merica.

[ABSTRACT.]

THE attention of the author has been directed to a curious and instructive case of local corrosion or pitting in tinned sheet copper roofing. The pits occur in general along the line of surface scratches, having appeared some 8 or 10 years after completion of the roof. These pits are apparently unrelated to the service conditions, and to the direction of rolling of the sheet.

A study of the structure of tin coatings on copper has been made, and has shown that this coating consists of at least 3 layers, viz., a thin layer of Cu_3Sn immediately next to the copper, then a layer of Heycock and Neville's constituent H, containing about 60 per cent. by weight of tin, and finally, a layer of the eutectic of tin and copper, in which is found most probably also the lead when it is present in the tinning mixture. This coating in the case of the corroded sheet was thin, averaging about 0.012 mm. in thickness, and quite variable in both thickness and struc-

* Technologic Paper No. 90. A copy of this paper may be obtained by application to the Bureau of Standards, Washington, D. C.

ture, varying from 0.006 mm. to 0.03 mm. in thickness. At many points there were breaks in the continuity of the alloy layer; at others, breaks in the continuity of the eutectic layer.

Etching experiments and measurements of electrolytic EMF of these layers toward various solutions, such as water, dilute acids, and acids to which ferric or stannous chlorides had been added, showed that the constituents of these intermediate alloy layers are more electronegative, *i.e.*, less corrodible, than either the tin or the copper. Values were found for the EMF of these alloy constituents against copper in various solutions varying from −5 to −80 millivolts.

When the copper becomes exposed, therefore, as in the present case at the bottom of the scratches on the surface, it forms together with the alloy layer a galvanic couple, electrolytic action sets in, and the copper at these points is corroded, forming the pits described.

Many instances are known, of course, of roofs of such material, which have been in service for 20 and more years, under severer conditions, as regards smoke, soot, etc., etc., than were those under which the roofing in question failed, and which nevertheless have not shown sign of such pitting. Explanation of this variation in service rendered by different samples of the same type of roofing material must be sought in the variation of mechanical abuse, such as scratching, which it receives, and also in the uniformity of structure and thickness of the tin coating.

Stellite vs. High-speed Steel. R. Sylvany and H. Haeffely. (*La Chronique Industrielle*, vol. 39, No. 279, p. 6, December 28, 1917.)—According to an account given in *Metaux et Alliages*, the hard non-ferrous alloy, stellite, invented three or four years ago in the United States by Elwood Haynes, marks a still greater advance in the art of cutting metals than established by the notable results obtained with the introduction of high-speed steel some years earlier. Where rate of production is a critical matter, as in the manufacture of ammunition, it has already made a remarkable record in competition with high-speed steel, a material which in point of capacity of production outclassed steels previously used. One of the advantages of stellite is that its hardness, which it maintains even at a red heat, is solely dependent upon the composition of the alloy, tungsten and chromium with additions of cobalt and molybdenum, and not upon the difficult and uncertain operations of heat treatment. Its funda-

mental advantage, however, lies in its ability to withstand a marked increase in speeds and feeds over those previously used with high-speed steels.

Among the already numerous machine shops employing stellite, the Fonderie des Gobelins in Paris reports that a daily production with high-speed steel of 120 shells of 155 mm. was increased to 200 by the use of stellite. With high-speed steel 21 minutes were consumed in roughing out at a speed of 17 meters and a feed of 0.7 mm. For finishing, the same speed and feed were employed and the same time was consumed. With stellite the roughing-out occupied 11 minutes at a speed of 25 meters and a feed of 0.85 mm. For finishing a speed of 37 meters was maintained with a feed of 1.67 mm. consuming 4 minutes. For completely finishing 1000 shells of 155 mm., the cost of stellite is about 0.30 francs per shell. Other firms report equally favorable results in this class of work.

Sub-aqueous Mining of Anthracite Coal. P. A. ROCHE. (*Scientific American*, vol. cxvi, No. 4, p. 98, January 27, 1917.)—Present day conditions as to the utilization of anthracite coal are now so acute that we find in actual operation plants to recover from river beds by sub-aqueous mining the fuel that for nearly three generations has been buried under water in many of the streams that flow through the extensive anthracite coal regions. The smooth surfaces worn by attrition, it is true, have not the glitter of the freshly mined "black diamond," but the combustion value is in nowise impaired, for it happens that the product is the best coal of the mines. These deposits of coal, found in deep layers just above dams, and in pockets where small river whirlpools existed, are easily reached; and the centrifugal pump, traveling bucket conveyor, and even the Archimedes screw are now winning between half a million and a million tons yearly of this previously ignored valuable material.

In the Schuylkill region a move was initiated towards a systematic modern handling of coal laden river bottoms, and it may be remarked that the past half dozen years has seen a great increase in the number of dredging plants throughout the anthracite coal country. No land need be purchased as for surface mining; no driving of shafts, etc., and in many cases no payment of royalties: an investment of $2000 in a pumping plant, second hand canal boats and like equipment, and the river operator is equipped for work. At the most liberal estimate the cost of getting the coal out of the water is 12 cents per ton. The price paid by one consumer who uses nearly the whole output of two of these plants, each consisting of one battery of pumps, is $1.35 per ton at the point where shipment begins.

The Susquehanna and Schuylkill as well as the Lehigh are surrendering the buried coal. With closer and more scientific working up of the coal as it comes from the mines, the ugly, disfiguring culm dumps spread over a naturally picturesque landscape will be a thing of the past, and perhaps the small river industry too, but hardly for a generation or more.

NOTES FROM NELA RESEARCH LABORATORY.*

THE QUALITY OF LIGHT FROM AN ILLUMINANT AS INDICATED BY ITS COLOR TEMPERATURE.

By E. P. Hyde and W. E. Forsythe.

THE importance of quality in the light from various illuminants has been recognized for some time, and various methods have been worked out to designate this important characteristic. The spectrophotometer may be used to determine the relative distribution of intensity in the various wave-lengths of the visible spectrum, and the colorimeters of Ives and of Nutting indicate component elements which may be used to specify the color of a light-source. But it is difficult, from such data, to visualize the resultant color.

It has been found by experiment that the light from most, but not all, ordinary illuminants can be matched in color by the light from a black body operating at some particular temperature, which is called the " color " temperature of the source in question. In the case of candles, oil lamps, ordinary gas flames, and incandescent electric lamps, it is found that, when operating at a color match, the distribution of energy in the visible spectrum of the black body and the source is quite closely the same, although this would not necessarily follow.

Data have been obtained on the color temperatures of various illuminants, and it is suggested that these be made the basis of a color scale for sources whose light is sufficiently near that of a black body in color to permit of comparison.

For sources, such for example as the Welsbach mantle, whose light cannot be matched in color with that from a black body at any temperature, the method outlined above is not entirely satisfactory, but the authors have in mind a possible modification of this method which may extend its applicability to almost all practical sources. Experiment has shown that it is possible to specify the quality of light from the Welsbach mantle, whose color in somewhat greenish, by stating the temperature of a black body whose light when mixed with that transmitted by a blue-green

* Communicated by the Director.

filter and coming from a black body at a definite temperature matches that from the mantle. Further investigation is planned to determine the feasibility of some such method for those sources whose colors do not lie on the scale of color of a black body at various temperatures.

Data for some of the most common illuminants are given in the table.

COLOR TEMPERATURE OF VARIOUS ILLUMINANTS.

Source	Color temperature °K.
Gas flame, fish tail burner *	1870
Hefner	1875
Pentane (10 candle-power standard)	1914
Candle:	
Paraffin	1920
Sperm	1925
Kerosene lamp:	
Round wick	1915
Flat wick	2045
Acetylene (as a whole)	2368
One spot	2448
2.3 w.p.h.c. Nernst glower	2388
4.0 w.p.h.c. carbon	2070
3.1 w.p.h.c. treated carbon	2153
2.5 w.p.h.c. Gem	2183
2.0 w.p.h.c. Osmium	2176
2.0 w.p.h.c. Tantalum	2249
1.25 w.p.h.c. tungsten	2385
0.9 w.p.h.c. tungsten	2543
0.5 w.p.h.c. gas-filled tungsten	2900 †

* Coal and water gas mixture. Approximately 600 B. T. U.
† Approximate. Differs with different lamps.

From these data and those on the black-body brightness temperatures, the brightnesses of the various illuminants may be computed.

THE REFLECTIVITY OF TUNGSTEN IN THE INFRA-RED.

By W. Weniger and A. H. Pfund.

IN this investigation on the reflectivity of tungsten, there were measured for the wave-length interval 0.59μ to 4.0μ

(1) The absolute reflectivity at room temperature, and
(2) The change in reflectivity from that at room temperature for several temperatures up to 2056° K.

Three tungsten mirrors were used, one polished Coolidge X-ray target, and two polished flattened wires mounted in evacuated soft glass bulbs, with terminals for heating electrically. All mirrors gave concordant values at the points at which they were compared. The spectrometer was provided with a fluorite prism and a bolometer. The length of air-path, the number of silvered reflecting surfaces, and the angles of reflection from these surfaces were kept constant in all measurements. Slit-width corrections were applied. The temperatures were measured by Worthing and Forsythe on an optical pyrometer.

The results obtained are summarized in the following table:

Wave-length in μ	Absolute reflectivity at room temperature in per cent.	Per cent. increase in reflectivity in going from room temperature to			
		1377° K.	1628° K.	1853° K.	2056° K.
0.67	51	+6.0	+7.4	+8.7	+9.8
0.80	55				+8.2
1.27	70	0.0	0.0	0.0	0.0
1.90	83	−6.6	−8.2	−9.6	−11.0
2.00	85	−7.5	−9.3	−10.9	−12.3
2.90	92	−7.7	−9.4	−11.1	−12.5
4.00	93				−12.5

THE ROTATION OF CONSTANT DEVIATION PRISMS.

By W. E. Forsythe.

THE constant deviation prism, as used in the well-known Hilger spectroscope, is so mounted and so rotated that the incident beam passes through the prism in such a manner that its axis coincides very closely with the axis of the prism. As a result of this arrangement light of only two wave-lengths can pass through the prism at exactly minimum deviation. For all other wave-lengths there is a lateral shift of the beam.

If the spectroscope is to be used to measure radiation rather than to locate spectral lines, a fixed diaphragm is necessary. In this case, at least, it would be well to have the prism so mounted and so rotated that it will remain in the position of minimum deviation.

It can be shown mathematically and has been found experimentally that if the prism be rotated about the line of intersection of the bisector of the ninety-degree angle of the prism and the

reflecting face, the prism will remain in the position of minimum deviation for all wave-lengths.

A method has been worked out of locating the prism on the prism table very close to the correct position. It has been found convenient to have the prism table equipped with stops so that the prism can be removed and replaced on the prism table in the proper position without as much trouble as is ordinarily encountered.

NELA PARK, CLEVELAND, OHIO,
February 20, 1917

The Chemical Industry of Switzerland. ANON. (*Metallurgical and Chemical Engineering*, vol. xvi, No. 2, p. 78, January 15, 1917.)—Switzerland is one of those countries which, although covered by a vast area of mountainous terrain, is exceptionally poor in all kinds of mineral resources. The main raw materials, coal and iron, are practically lacking and necessitate their importation from the surrounding nations. Water power is, however, available and is being developed to its full capacity. The war has to a great extent thrown this small country on its own resources as far as power for industrial purposes is concerned, but at the best this power source is insufficient to supply the 107 chemical plants at present in operation. The bulk of the coal, therefore, is at present obtained from Germany. Previous to the war coal was also imported from France.

Practically all the chemical engineers of the country are trained at the polytechnicum of Zurich and the University of Zurich, both being independent of one another and financed by the government. The most important chemical industry is undoubtedly the manufacture of synthetic dyes. Besides this branch, Switzerland manufactures pharmaceutical products and chemicals for industrial purposes. These are two types of colors produced, namely, vegetable dyes, chiefly from logwood, and coal tar colors. At least 106 synthetic dyes are at present produced by the various dye factories of the country. These dyes at present are mainly shipped to England and France, but would under normal conditions be available for the American market. Among the pharmaceutical preparations manufactured are protargol, collargol, and itral, a new preparation of a silver protein compound carrying 30 per cent. silver and sold under various trade names. There are also produced, alkaloids, perfumes, cosmetics, and, for industrial purposes, acid potassium tartrate, boric acid, phosphoric acid, sodium, tanning extracts, glycerin, methyl alcohol, coal-tar derivatives, benzychloride, glue and gelatin. The first chemical factory was built in the year 1764. From that time up to date the number has increased to 107.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, February 21, 1917.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 21, 1917.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 11.

Mr. William C. Wetherill, chairman of the Committee on Science and the Arts, reported the condition of the work of the committee.

The standing committees for the year 1917–1918 were announced.

Mr. Alfred W. Gibbs made the following statement:

"In order to meet the formalities necessary in the sale, by the Trustees of the Institute, of the Doylestown Farm, which came to the Institute under the will of the late William H. Wahl, it is necessary that the following resolution be passed:

"'*Resolved*, That the title to the tract of land situated in the Township of Doylestown, County of Bucks and State of Pennsylvania, containing twenty-four acres of land more or less, recently devised to The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, under the will of William H. Wahl, deceased, be transferred to the Board of Trustees, in accordance with Section I, Article I, of the By-Laws of the Institute. And the President and Secretary of the Institute are hereby authorized and directed to execute the necessary deed for the purpose.'"

The resolution was duly seconded and passed unanimously.

The paper of the evening, entitled "Reclaiming the Everglades of Florida," was presented by Dr. Isham Randolph, Consulting Engineer, Chicago, Ill. The speaker described his experience in Florida during the past four years, and the work which has been done in the Everglades, along the Kissimmee River, on Lake Okeechobee, on the headwaters of the St. John's River, and on Biscayne Bay. He referred to the beauties of Florida, the productiveness of its swamp and other lands, and outlined the engineering difficulties being overcome in its development. The subject was illustrated by lantern slides.

At the close of the paper a vote of thanks was extended to the speaker and the meeting adjourned.

R. B. OWENS,
Secretary.

STANDING COMMITTEES, 1917.

OF THE BOARD.

ELECTIONS AND RESIGNATIONS.

Alfred W. Gibbs, Chairman,
Kern Dodge,
W. C. L. Eglin,
George R. Henderson,
George D. Rosengarten.

ENDOWMENT.

Coleman Sellers, Jr., Chairman,
Alfred C. Harrison,
G. H. Clamer,
Richard Waln Meirs,
Wm. Chattin Wetherill.

EXECUTIVE.

E. H. Sanborn, Chairman,
Charles Day,
Walton Forstall,
Alfred C. Harrison,
Richard Waln Meirs.

EXHIBITIONS.

Francis T. Chambers, Chairman,
Nathan Hayward,
C. A. Hexamer,
Marshall S. Morgan,
Benjamin Franklin,

INSTRUCTION.

Lawrence T. Paul, Chairman,
George A. Hoadley,
Harry F. Keller,
Edw. V. McCaffrey,
James S. Rogers.

PUBLICATIONS.

Louis E. Levy, Chairman,
W. C. L. Eglin,
George A. Hoadley,
E. H. Sanborn,
George D. Rosengarten.

SECTIONAL ARRANGEMENTS.

Charles Day, Chairman,
Theobald F. Clark,
Harry F. Keller,
Robert W. Lesley,
Louis E. Levy.

STOCKS AND FINANCE.

Walton Forstall, Chairman,
Cyrus Borgner,
Alfred C. Harrison,
Richard Waln Meirs,
E. H. Sanborn.

OF THE INSTITUTE.

LIBRARY.

H. J. M. Creighton,
George A. Hoadley,
Harry F. Keller,
Gaetano Lanza,
Henry Leffmann,
Louis E. Levy,
Marshall S. Morgan,
Paul Spencer,
George F. Stradling,
William Chattin Wetherill.

MEETINGS.

Gellert Alleman,
Charles Baskerville,
G. H. Clamer,
Allerton S. Cushman,
George R. Henderson,
Herbert E. Ives,
A. E. Kennelly,
M. M. Price,
James S. Rogers,
George D. Rosengarten.

MUSEUM.

J. Snowden Bell,
Hugo Bilgram,
Arthur L. Church,
Fred. H. Colvin,
Henry F. Colvin,
Charles Day,
George A. Hoadley,
Henry Howson,
A. E. Outerbridge, Jr.,
Coleman Sellers, Jr.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, February 7, 1917.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 7, 1917.

MR. W. C. WETHERILL *in the Chair.*

The following report was presented for first reading:

No 2681.—International Money Machine.

Representatives of the International Money Machine Company appeared before the Committee and explained the operation and construction of the Money Machine.

The following report was presented for final action:

No. 2668.—Linear Hot-Wire Anemometer.

Howard N. Potts Medal to Prof. Louis Vessot King, of McGill University, Montreal, Canada, adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A joint meeting of the Section and the American Society of Mechanical Engineers was held in the Hall of the Institute on Thursday, February 1, 1917, at 8 P.M.

Mr. Emmett B. Carter, Chairman of the local Section of the American Society of Mechanical Engineers, occupied the chair.

Mr. Carter introduced Mr. C. J. Ramsburg, Vice-president, H. Koppers Company and Pittsburgh By-Product Coking Company, Pittsburgh, Pa., who delivered a lecture entitled "The By-Product Coking Industry."

This lecture, which was fully illustrated by the use of lantern slides and moving pictures, treated of the design, construction and operation of the modern by-product plant; coal used in by-product coking; coke structures as affected by coals; conditions affecting the efficiency of operation and recovery; future of the industry. Special attention was given to benzol and benzol recovery.

After an interesting discussion, a vote of thanks was extended to the speaker.

Adjourned,

T. R. PARRRISH,
Acting Secretary.

Electrical Section.—A joint meeting of the Section and the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday, February 8, 1917, at 8 P.M.

Mr. Charles E. Bonine and Mr. H. P. Liversidge presided jointly.

Alexander Gray, M. Sc., Professor of Electrical Engineering, Cornell University, Ithaca, N. Y., delivered a lecture entitled "Modern Dynamo Electrical Machinery, With Special Reference to Power and Traction Uses." The recent developments in electrical machinery were discussed under the following heads:

Discussion of the limits of direct-current machines.

Development of direct-current machines in the last ten years, showing the effect of interpoles and compensating windings on the speed and output.

Development of turbo and of water-wheel driven alternators, with a discussion of the problems of mechanical design and ventilation; also the effect of the automatic regulator on the design and on the output.

Development of the Rotary Converter, giving the reasons for the success of the sixty-cycle rotary in large sizes and for the high speeds now in use.

After an interesting discussion, a rising vote of thanks was extended to the speaker, and the meeting adjourned.

T. R. PARRISH,
Acting Secretary.

Mining and Metallurgical Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 15, 1917, at 8 P.M.

Prof. A. E. Outerbridge, Jr., occupied the chair.

Prof. Outerbridge introduced Mr. Howard W. DuBois, Consulting Mining Engineer, of Philadelphia, Pa., who delivered a lecture entitled "Oil Concentration of Ores."

The radical change in established methods of ore concentration in a comparatively short period of time by the introduction of the oil flotation process, with its resulting extraordinary economies, constitutes one of the most striking chapters in the history of ore milling operations. The oil process is chiefly characterized by the use of extremely small quantities of oil. The action of the oil appears to be restricted to coating the surface of the metallic sulphide particles with a thin film, making them attractive to air particles in the water and thus causing them to float, while the gangue, which is non-metallic, is wetted and sinks. The origin of this already widely applicable process, the principles of its operation, and its most recent developments were discussed.

After an interesting discussion, the thanks of the meeting were extended to the speaker.

Adjourned,

T. R. PARRISH,
Acting Secretary.

MEMBERSHIP NOTES.

Stated Meeting, Board of Managers, February 14, 1917.

ELECTIONS TO MEMBERSHIP.

RESIDENT.

MR. ARTHUR N. BLUM, chief engineer, Henry Disston & Sons, Inc., Tacony, Philadelphia, Pa.

MR. JOHN GAREY, chemist, American Dyewood Company, and for mail, in care of Y. M. C. A., Chester, Pa.

MR. ANTHONY M. HANCE, manufacturing chemist, 201 Walnut Place, Philadelphia, Pa.

MR. HENRY J. STEUBER, chemist, 509 South Tenth Street, Philadelphia, Pa.

NON-RESIDENT.

DR. A. D. CHAMBERS, chemical engineer, E. I. du Pont de Nemours and Company, and for mail, 1519 Franklin Street, Wilmington, Del.

MR. J. KING MCLANAHAN, president, McLanahan & Stone Machine Company, Hollidaysburg, Pa.

MR. FRANK S. MACGREGOR, Development Department, E. I. du Pont de Nemours and Company, 452 du Pont Building, Wilmington, Del.

MR. ALEXANDER ERNEST REOCH, chief engineer, Marconi Wireless Telegraph Company of Canada, Ltd., Montreal, P. Q., Canada.

MR. CHARLES E. RICHARDSON, secretary, The Surface Combustion Company, and for mail, 63 East Fifty-ninth Street, New York, N. Y.

MR. F. W. SPERR, JR., chief chemist, H. Koppers Company Laboratory, Mellon Institute, Pittsburgh, Pa.

MR. HUGH P. TIEMANN, assistant metallurgical engineer, Carnegie Steel Company, Pittsburgh, Pa.

CHANGES OF ADDRESS.

MR. HAROLD V. COES, care of Gunn, Richards & Co., 43 Exchange Place, New York, N. Y.

PROF. W. S. FRANKLIN, Orange City, Florida.

DR. JACOB S. GOLDBAUM, 4636 Walnut Street, Philadelphia, Pa.

MR. WILLIAM J. HAMMER, 55 Liberty Street, New York, N. Y.

MR. ELMER K. HILES, 5712 Hampton Street, Pittsburgh, Pa.

MR. EDWIN W. KELLY, 737 West Van Buren Street, Chicago, Ill.

MR. HENRY M. KOLB, 1400 Widener Building, Philadelphia, Pa.

MR. MORTON G. LLOYD, Bureau of Standards, Washington, D. C.

MR. FRANK M. MASTERS, 204 Locust Street, Harrisburg, Pa.

MR. FRED. J. MILLER, 374 Broadway, New York, N. Y.

DR. R. W. RUPRECHT, care of F. W. Tunnell & Co., Wheatsheaf Lane and Gaul Street, Philadelphia, Pa.

MR. OSCAR L. SCHEHL, care of American Machine and Foundry Co., Brooklyn, N. Y.

MR. A. F. SHATTUCK, Angelus Hotel, Los Angeles, Cal.

NECROLOGY.

Mr. Robert D. Jenks, Esq., was born at Enterprise, Florida, in 1875 and died in Philadelphia, on January 22, 1917.

He was educated at the Penn Charter School in Philadelphia and Harvard University. Later he entered the University of Pennsylvania and was graduated from its law department in 1901. In the practice of law he devoted special attention to railroad rate cases and questions relating to interstate commerce.

Mr. Jenks was the author of "A Handbook of Commercial Law for Business Men" and made frequent contributions on interestate commerce law to the legal magazines.

He was greatly interested in civil service reform and was a member of the national and local organizations devoted to the furtherance of the matters.

Mr. Jenks became a member of The Franklin Institute in 1898.

Prof. Arthur Beardsley, Swarthmore, Pa.

Mr. Thomas C. McCollom, U.S.N., retired, 4606 Springfield Avenue, Philadelphia, Pa.

Mr. Alex. P. Robinson, 4603 Woolworth Building, New York City, N. Y.

LIBRARY NOTES.

PURCHASES.

AMERICAN ANNUAL OF PHOTOGRAPHY.—Vol. 31. 1917.

AMERICAN CONCRETE INSTITUTE.—Proceedings. Vol. 12. 1916.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS.—Transactions. Vol. 8. 1915.

ATTWOOD, E. L.—Text-book of Theoretical Naval Architecture. 1916.

BOND, P. S.—The Engineer in War. 1916.

BRAGG, E. M.—Design of Marine Engines and Auxiliaries. 1916.

HAMILTON, D. T.—Cartridge Manufacture. 1916.

HAMILTON, D. T.—High-explosive Shell Manufacture. 1916.

HAMILTON, D. T.—Shrapnel Shell Manufacture. 1915.

HARDING, L. A., and WILLARD, A. C.—Mechanical Equipment of Buildings. 1916.

HARGER, W. G., and BONNEY, E. A.—Handbook for Highway Engineers. 1916.

LUCKIESH, M.—Light and Shade and Their Applications. 1916.

MORSE, H. N.—The Osmotic Pressure of Aqueous Solutions. 1914.

OMMUNDSEN, H., and ROBINSON, E. H.—Rifles and Ammunition and Rifle Shooting. 1915.

GIFTS.

Abrasive Company, Catalogue No. 6, Abrasive Grinding Wheels. Philadelphia, 1916. (From the Company.)

Alabama Geological Survey, Bulletin No. 17, Second Report of the Water Powers of Alabama. University, 1916. (From the Survey.)

American Institute of Electrical Engineers, Transactions, vol. xxxiv, parts I and II, January to December, 1915. New York, 1915. (From Dr. R. B. Owens.)

American Railway Tool Foremen's Association, Year Book, 1916. Chicago, 1916. (From the Association.)

American Society of Mechanical Engineers, Year Book, 1917. New York, 1917. (From the Society.)

Amherst College, Catalogue, 1916–1917. Amherst, Massachusetts, 1916. (From the College.)

Arrhenius, Svante, Theories of Solutions. New Haven, Conn., 1913. (From Yale University.)

Baldwin Locomotive Works, Circular No. 1516-A, Baldwin-Westinghouse Electric Locomotives. Philadelphia, 1916. (From the Works.)

Bateson, William, Problems of Genetics. New Haven, Conn., 1916. (From Yale University.)

Campbell, William Wallace, Stellar Motions, With Special Reference to Motions Determined by Means of the Spectrograph. New Haven, Conn., 1913. (From Yale University.)

Canada Department of Mines, Mines Branch, Summary Report, 1915; and A General Summary of the Mineral Production, 1915. Ottawa, 1916. (From the Department.)

Canada, Minister of Public Works, Report of the Works Under His Control for the Fiscal Year Ended March 31, 1916. Ottawa, 1917. (From the Minister.)

Canal Record, vol. ix, August 25, 1915, to August 16, 1916. Balboa Heights, Canal Zone, 1916. (From the Panama Canal.)

Case School of Applied Science, Catalogue, 1916–1917. Cleveland, 1916. (From the School.)

Dartmouth College, The Catalogue, 1916–1917. Hanover, N. H., 1916. (From the College.)

Dixon, Joseph, Crucible Company, Graphite, vol. xviii, January to December, inc. 1916. Jersey City, 1916. (From the Company.)

Doehler Die-Casting Company, Creating an Industry. Brooklyn, 1916. (From the Company.)

Georgia School of Technology, Catalogue, 1915–1916. Atlanta, 1916. (From the School.)

Goldschmidt Thermit Company, Pamphlet No. 17, Thermit Mill and Foundry Practice. New York, 1915. (From the Company.)

Grand Army of the Republic, Department of Pennsylvania, Proceedings of the Fiftieth Annual Encampment, 1916. Harrisburg, 1916. (From the State Librarian.)

Hampden Corundum Wheel Company, Catalogue of Hampden Grinding Wheels. Springfield, Mass., 1916. (From the Company.)

Harrison Safety Boiler Works, Catalogue No. 710, Cochrane Heaters. Philadelphia, 1916. (From the Works.)

Hudson and Thurber Company, Catalog D. Minneapolis, Minn., 1914. (From the Company.)

Hunt, Rodney, Machine Company, Catalogue No. 30, Water Controlling Apparatus. Orange, Mass., 1916. (From the Company.)

Iddings, Joseph P., The Problem of Volcanism. New Haven, Conn., 1914. (From Yale University.)

Illinois State Geological Survey, Bulletins Nos. 20, 24, 26, 27, 31, and 32. Urbana, 1915–1916. (From the Survey.)

Illinois State Mining Board, Thirty-fifth Annual Coal Report, 1916. Springfield, 1916. (From the Board.)

India Geological Survey, Memoirs, Palæontologia Indica, New Series, vol. v, Memoir No. 3. Calcutta, 1916. (From the Survey.)

Ladd, George T., Company, Catalogue No. 17, Ladd Water Tube Boiler. Pittsburgh, no date. (From the Company.)

Lakewood Engineering Company, Books Nos. 16 and 17. Cleveland, Ohio, no dates. (From the Company.)

Leland Stanford Junior University, Annual Report of the President for the Twenty-fifth Academic Year ending July 31, 1916; and A Study of the Magmatic Sulfid Ores, by C. F. Tolman, Jr., and Austin F. Rogers. Stanford University, California, 1916. (From the University.)

Manchester Association of Engineers, Transactions, Session 1915–1916. Manchester, 1916. (From the Association.)

Massachusetts Institute of Technology, Catalogue, December, 1916. Cambridge, 1916. (From the Institute.)

Master Car Builders' Association, Report of the Proceedings of the Fiftieth Annual Convention, 1916, Parts I and II. Chicago, 1916. (From the Association.)

Michigan Gas Association, Proceedings of the Twenty-fifth Annual Meeting, 1916. Lansing, 1916. (From the Association.)

Michigan State Board of Agriculture, Fifty-fifth Annual Report, 1916. Lansing, 1916. (From the Board.)

Midvale Steel Company, Catalogue No. 33, Alloy and Tool Steel. Philadelphia, 1916. (From the Company.)

Montana Railroad and Public Service Commission, Ninth Annual Report, 1916. Helena, 1916. (From the Commission.)

Mount Holyoke College, The Catalogue, 1916–1917. South Hadley, Mass., 1916. (From the College.)

National Physical Laboratory, Report for the Year 1915–16. Teddington, Middlesex, England, 1916. (From the Laboratory.)

Nernst, Walther, Experimental and Theoretical Applications of Thermodynamics to Chemistry. New Haven, 1913. (From Yale University.)

New Jersey Department of Conservation and Development, Bulletin No. 17. Revision of Primary Levels and List of Bench Marks in Northern New Jersey. Trenton, 1916. (From the Department.)

New South Wales Government Statistician, Vital Statistics for 1915. Sydney, 1916. (From the Statistician.)

New York Conservation Commission, Fifth Annual Report, 1915. Albany, 1916. (From the Commission.)

Pennsylvania Auditor General, Report, 1915. Harrisburg, 1916. (From the State Librarian.)

Pennsylvania Department of Mines, Report, 1915, Part II, Bituminous. Harrisburg, 1916. (From the State Librarian.)

Pennsylvania Insurance Commissioner, Forty-third Annual Report, 1915. Part II, Life and Accident Insurance. Harrisburg, 1916. (From the State Librarian.)

Philadelphia Chamber of Commerce, Year Book, 1917. Philadelphia, 1917. (From the Chamber.)

Pittsburgh Valve and Fittings Company, Catalogue D. Barberton, Ohio, 1916. (From the Company.)

Problems of American Geology, A Series of Lectures delivered at Yale University, December, 1913. New Haven, Conn., 1915. (From Yale University.)

Queensland Geological Survey, Department of Mines, Publication No. 254, The Glossopteris Beds of Betts' Creek, Northern Queensland. Brisbane, 1916. (From the Survey.)

Royal Society of New South Wales, Journal and Proceedings, vol. xlix, Part. iv, 1915. Sydney, 1915. (From the Society.)

Rutherford, E., Radioactive Transformations. New Haven, Conn., 1906. (From Yale University.)

Sherrington, Charles S., The Integrative Action of the Nervous System. New Haven, Conn., 1911. (From Yale University.)

Smithsonian Institution, A Contribution to the Comparative Histology of the Femur, by J. S. Foote. Washington, 1916. (From the Institution.)

Smythe, R. M., Obsolete American Securities and Corporations. New York, 1904. (From the Philadelphia Book Company.)

Stevens Institute of Technology, Annual Catalogue, 1917–1918. Castle Point, Hoboken, N. J., 1917. (From the Institute.)

Stevenson, Robert Louis, Memoir of Fleeming Jenkin. New York, 1887. (From Dr. R. B. Owens.)

Sturtevant, B. F. Company, Binder B. containing Bulletins and Catalogues. Hyde Park, Boston, Mass., 1916. (From the Company.)

Tasmania Secretary for Mines, Report, 1915. Hobart, 1916. (From the Secretary.)

Thomson, J. J., Electricity and Matter. New Haven, Conn., 1904. (From Yale University.)

University of Cincinnati, Annual Catalogue 1916–1917. Cincinnati, Ohio, 1917. (From the University.)

University of Maine, Catalogue, 1916–1917. Orono, 1916. (From the University.)

U. S. Coast and Geodetic Survey, Annual Report for the Fiscal Year Ended June 30, 1916; and Special Publication No. 40, Investigations of Gravity and Isostasy, by William Bowie. Washington, 1916–1917. (From the Survey.)

Verworn, Max., Irritability, A Physiological Analysis of the General Effect of Stimuli in Living Substances. New Haven, Conn., 1913. (From Yale University.)

PUBLICATIONS RECEIVED.

Handbook of Engineering Mathematics, by Walter E. Wynne, B. E., and William Spraragen, B. E. 220 pages, illustrations, 16mo. New York, D. Van Nostrand Company, 1916. Price, $2.00.

Principles of Quantitative Analysis, An Introductory Course, by Walter C. Blasdale, Ph.D., associate professor of chemistry, in the University of California. Second edition, revised and enlarged. 402 pages, illustrations, 12mo. New York, D. Van Nostrand Company, 1917. Price, $2.50.

"Mechanical World" Pocket Diary and Year Book for 1917, A collection of useful engineering notes, rules, tables and data. 453 pages, illustrations, 16mo. Manchester, England, Emmott and Company, no date; representatives in the United States, The Norman, Remington Company, Baltimore, Md. Price, postpaid, 40 cents.

Canada Department of Mines, Mines Branch, Summary report for the cal-

endar year ending December 31, 1915. 213 pages, illustrations, tables, plates, maps, 8vo. Ottawa, King's printer, 1916. Price, 25 cents.

United States Bureau of Mines, Bulletin 107, Prospecting and Mining of Copper Ore at Santa Rita, New Mexico, by Donald F. Macdonald and Charles Enzian, 122 pages, illustrations, plates, maps. Bulletin 111, Molybdenum; its ores and their concentration with a discussion of markets, prices, and uses, by Frederick W. Horton, 132 pages, illustrations, plates. Technical paper 88, Mineral Technology 6, The radium-uranium ratio in carnotites, by S. C. Lind and C. F. Whittemore, 29 pages, illustrations, plate. Technical paper, 135, Bibliograhy of recent literature on flotation of ores, January to June, 1916, compiled by D. A. Lyon, O. C. Ralston, F. B. Laney and R. S. Lewis, 20 pages. Technical paper 138, Suggested safety rules for installing and using electrical equipment in bituminous coal mines, by H. H. Clark and C. M. Means, 36 pages. Monthly statement of coal-mine fatalities in the United States, November, 1916. List of permissible explosives, lamps, and motors tested prior to December 31, 1916, compiled by Albert H. Fay, 30 pages. Washington, Government Printing Office, 1916–1917.

United States Department of Agriculture, Bulletin 390, Public road mileage and revenues in the United States, 1914. A summary showing for each state total and surfaced mileage of public roads at the close of 1914 revenues for roads and bridges in 1914, state and local road and bridge bonds outstanding January 1, 1915, and other related data. 11 pages, 8vo. Washington, Government Printing Office, 1917.

New Method for Charging Storage Batteries. ANON. (*Electrical World*, vol. 68, No. 26, December 23, 1916.)—In a recent patent (No. 1,205,620) Varian M. Harris, Chicago, Ill., the inventor, gives an interesting theory of the apparent inefficiency observed when charging storage batteries from rectified or pulsating circuits. In the charging of a storage battery an appreciable time element is necessary for the chemical reactions to take place within the battery, and for that reason if a phase wave is cut at the points which correspond in voltage to the voltage of the battery, the latter will not be charged. since it does not respond instantaneously to the current which passes into it, and sparking will result.

In order to overcome this difficulty the phase waves should be cut at appropriate points so that the rectified current passes to the battery at a voltage considerably below the normal voltage of the battery. The chemical changes immediately begin to take place in the battery, and by thus allowing the current to flow to the battery at a decreased voltage the chemical changes have become sufficiently started so that when the voltage of rectified current reaches the normal voltage of the battery, the rectified current is allowed to flow to the battery. This result is accomplished by constructing the segments of the mechanical rectifier of such a width that the phase waves of the rectified current are cut at a voltage sufficiently below the normal voltage of the battery that the time during which the rectified current is increasing up to the voltage of the battery is sufficient to overcome the electrolytic lag of the latter.

CURRENT TOPICS.

The Root Mean Square Current Meter. D. C. HERSHBERGER. (*The Electric Journal*, vol. xiv, No. 2, p. 59, February, 1917.)—The heating effect of a variable electric current is proportional to the square root of the mean square current, which obviously is the square root of the average of the squares of the instantaneous current values for a given period of time, taken at infinitely short intervals. The longer these intervals, the more inaccurate will the results be, especially under rapidly changing current conditions. Hence, in determining the value of actual test, it is necessary to take current readings as frequently as possible, equal time intervals usually being most convenient. The determination of the root mean square current by ammeter method, where the current values are changing rapidly, is not only difficult, but tiresome and expensive work, especially when readings must be taken over a considerable period of time on a moving car or locomotive.

It is well known that the continuous capacity of any piece of electrical apparatus is limited by the amount of heat it can dissipate. In most electrical apparatus, the principal sources of internal heat are the copper and iron losses. In some apparatus these losses are entirely independent. In a series machine, the iron loss at a given voltage depends upon the current. In a railway motor, for instance, the generation of heat is due to both copper and iron loss, but its capacity is determined by the r.m.s. current (sometimes called the equivalent heating current), at which it can operate without exceeding a safe rise in temperature. Many other types of machines designed for intermittent service are given r.m.s. current ratings.

In order to measure this equivalent heating current expeditiously and economically, Mr. J. L. Davis in 1910 invented the original root mean square current meter. The measurement of current with this meter depends upon the generation of heat by passing all or part of the current through a resistance immersed in a given quantity of water. Since the heat generated is proportional to the square of the current, the temperature of the water will (except for heat losses) be raised in the same proportion. Every change of current will be virtually integrated, on the basis of the square of the current and elapsed time, by the rise in temperature of the water. Rapid radiation of heat is prevented by the use of a vacuum jar. The original meter consists of a "Thermos" bottle or similar vacuum jar containing water into which are immersed a resistance coil and a thermometer. The supporting terminals of the coil and thermometer pass through the cork. In operation, the temperature of the water tends

to be slightly higher at the top and stirring vanes attached to a rod are provided for mixing the water prior to reading the temperature. Starting with a definite quantity of distilled water at 20 degrees C., the instrument is kept in the circuit for a period of approximately two hours, provided the r.m.s. current does not exceed the rating of the resistance element or shunt. The test can, in fact, be started at any temperature which will permit it to be finished without bringing the water too near the boiling point. A correction factor is applied for initial temperatures which are more than 5 degrees above or below 20 degrees C. Equivalent current is read from temperature-time curves for different currents, determined from constant current readings. Results of careful laboratory tests show the error of the instrument is less than two per cent.

Some Special Applications of Pinhole Photography. ANON. (*British Journal of Photography*, vol. lxiv, No. 2959, p. 27, January 19, 1917.)—Very few photographers seem to appreciate what can be done with a pinhole when a lens suitable for a given purpose is not at hand. It happens sometimes that no lens of sufficiently great or perhaps short enough focal length is available, or possibly one that will cover a sufficiently wide angle. If, however, we can put up with less perfect definition and also long exposure, a great many things can be done with a simple pinhole, for focal length is a property that is practically infinitely elastic with a pinhole, while the angle of view can be any size up to very wide limits with a good hole. Also, depth is unlimited. As regards definition, the lack of sharpness is not nearly so great as is likely to be imagined by those unacquainted with what can be done. A good pinhole negative will give a lantern slide that will bear a considerable degree of enlargement on the lantern screen without any undue fuzziness. There is usually a certain amount of grain apparent, owing probably to the peculiar diffraction effects which go to form the image, but this need not be seriously objectionable. As regards focal length, we may consider anything feasible from about 40 inches down to an inch or less, consequently at small expense it is possible to secure effects that otherwise would be out of the question, neither 40-inch nor 1-inch lenses being available, as a rule.

Some of the most interesting results obtainable with the pinhole are those produced with exceedingly short extension, say an inch or so, for then we can get some idea of what the world looks like to some of the small creatures that inhabit it. Depth problems are immaterial to the pinhole, as all distances are alike to it. Using a camera consisting merely of a metal lantern slide box with a pinhole fitted with a small shutter, most interesting results in under-water photography have been obtained. For more ordinary purposes, it is often desirable to see beforehand on the focussing screen what amount of the subject is to be included on the plate. It is not possible to see the pinhole image on the screen, but if we substitute for the pinhole a

hole about a quarter of an inch in diameter, we can see the subject through it from any part of the plate area. In this way we practically turn the camera into a finder of the frame type, and this is all that is necessary, actual focussing being neither required nor possible.

Ferro-cerium and Other Pyrophoric Alloys. C. R. BOHM. (*Metal Record and Electroplater*, vol. iii, No. 1, p. 8, January, 1917.)—About the year 1903, Welsbach discovered that certain alloys of the rare earths, when filed, gave off showers of bright sparks which would readily ignite inflammable gases. It was subsequently found that the best results were secured when employing an alloy carrying about 65 per cent. cerium earth metals and about 35 per cent. iron. The same action takes place with these alloys as with the flint and steel, except that a spark is more easily produced than with the primitive tinder-box. The mixture of cerium earth metals, often called misch metal, consists mainly of the elements cerium, lanthanum, didymium, neodymium, praseodymium and samarium. All of these metals are white or light yellow in color and are not readily oxidized in air. When first produced, the price of ferro-cerium alloys was $60 per kilogram. Later, this was reduced to $12 per kilogram, and in 1913 to about $4.60 per kilogram. The present return to the old price is, of course, due to the abnormal conditions which have affected nearly all products.

While the original pyrophoric alloy or ferro-cerium manufactured by Welsbach contains nearly 40 per cent. of iron, the competing products possess only about 15 per cent. of iron, and for the purpose of hardening, about 2 per cent. of antimony or bismuth is added. Silicon is, of course, found in nearly all ferro-cerium alloys because it is either contained in the raw misch metal as an impurity, or has been absorbed from the clay crucibles in which the alloy is often produced. To insure a low-melting and smooth-casting pyrophoric alloy, certain manufacturers add about 5 per cent of copper. Most manufacturers produce ferro-cerium by the electrolysis of the anhydrous chlorides of cerium, lanthanum, didymium, etc., and it is necessary that cheap current be available. Many manufacturers use ordinary graphite or clay crucibles with large iron cathodes; others use water-jacketed iron crucibles.

Welding Glass in Optical Contact. G. R. PARKER AND A. J. DALLADAY. (*Engineering*, vol. ciii, No. 2663, p. 23, January 12, 1917.)—For many optical researches glass cells are wanted, formed by two strictly parallel walls or windows, and different pieces of glass, lenses and prisms, etc., have frequently to be united in such a way as to keep the surfaces optically true. Glass surfaces can be polished without difficulty to be so nearly plane or so nearly of the same curvature that they show less than one interference fringe per inch when placed together and examined by light reflected from the

interfaces. These surfaces may be brought into optical contact so that the two pieces of glass act optically as if they were one block by applying a pressure of several pounds per square inch. Unions so made may be easily separated by sudden heating or cooling by a shearing force, or by the application of liquids which gradually creep in between the surfaces.

A cell constructed of plates of glass in optical contact with a separating piece of U-shape could be made very accurately parallel; but the surfaces could be too easily separated again. Various cements like Canada balsam are, of course, largely used in optical combinations. But it is difficult by their aid to insure parallelism within one minute of the arc, and if the walls of the cell form a wedge of an angle of only a few seconds, instead of a cavity with plane-parallel walls, interference work may be seriously impaired. If pieces of glass could be welded without affecting the optical truth of their surfaces, considerable advantages would be gained. Attempts to effect such optical junctions by heating have been unsuccessful so far, though bifocal lenses are made by uniting two lenses either by cementing or by fusing; in the latter case, however, the flint is readily fused, and optically true contact is not aimed at.

The authors have succeeded by experiments in the research laboratories of Messrs. Adam Hilger, Limited, in producing some excellent specimens of optical welding. The secret of success lies, as might be expected, in the selection of the proper temperatures and pressures. It was found essential that the temperature at which union took place should not only be far below the melting point of the glasses to be joined, but also below the annealing temperature, for even at that latter temperature very slight strain would cause deformation of worked glass surfaces. At 60 degrees C., below the annealing temperature, it was found that two pieces of glass in optical contact would unite within an hour, and any slight deformation produced by the compression could be remedied by a few strokes of the polishing tool.

Lithographic Stone in the United States. ANON. (*U. S. Geological Survey Press Bulletin*, No. 308, February, 1917.)—In 1916 for the first time there was a considerable production of lithographic stone in this country. This production, according to information received by G. F. Loughlin, of the United States Geological Survey, Department of the Interior, was made by the Kentucky Lithograph Stone Company, which has quarries at Brandenburg, Ky., and an office in Louisville. In 1916 the company sold 40,000 pounds of finished stone at prices ranging from 2½ to 27 cents a pound. For some years previous small quantities had been sold occasionally in Louisville, but in 1916 the stone was shipped to buyers as far away as Cleveland, Washington, New York and Boston.

The quarry at Brandenburg contains three distinct beds from which lithographic stone may be obtained. Two of these beds are

about 3 feet thick and one 9 to 10 feet thick. They are separated by beds of limestone of other varieties and make up only about 20 per cent. of the stone that must be removed. The remaining 80 per cent., however, is available for crushed and pulverized limestone, chicken grit, and other uses, and considerable quantities were marketed for these purposes in 1916.

The greatest difficulty in the development of lithographic-stone quarries in the United States has been the high cost of quarrying and preparing the stone in competition with the well-known Bavarian stone. Much of this stone is reported to occur in thin layers that require only planing and polishing before use, whereas all known deposits in the United States that are at all suitable for lithographic work occur in more massive beds that must first be sawed into slabs of proper thickness. High cost of labor in the United States and of railroad as compared with ocean transportation have also stood in the way of the domestic industry.

Quarrying of the Bavarian stone, however, involves the handling of large quantities of waste, and the waste piles around the quarries to-day form hills of considerable size. The marketing of crushed stone and similar products from the Brandenburg quarry should go far toward eliminating the cost of quarrying from the expense of preparing lithographic stone. With this advantage it may be possible, even after the European war is over, to market the Kentucky stone in competition with the Bavarian stone, the better grades of which under normal conditions bring 5 to 6 cents a pound for 10 by 12 inch slabs, and the poorer grades 1½ cents a pound for slabs of the same size.

Uses of Colored Glass. H. P. GAGE. (*Transactions of the Illuminating Engineering Society*, vol. xi, No. 9, p. 1059, December 30, 1916.)—The uses of color in illuminating engineering may be divided into direct decorative effects, colored illumination for æsthetic effects, and illumination for specific visual effects. The direct decorative uses are seen in the stained glass windows of churches and in the coloring of illuminating reflectors and shades. Such decoration borders on the colored enamel such as is used in china and porcelain. Colored illumination is used in stage lighting and to produce the much desired warm tones in interior illumination. In these cases the light from the original source is filtered through either a colored lamp bulb or through a colored enclosing globe or even reflected from a colored reflector. The illumination for specific visual effects includes protection either of the eye or the work from harmful radiations. An example of the latter is the use of a red light for photographic purposes where the plate is not sensitive to red and the eye is.

Protection of the eye from harmful radiation may consist in the removal of the ultra-violet such as is met with in experimenting

with the arc lamp or in arc welding. It is, moreover, possible, although the eye was developed for use in natural daylight, that in such daylight the radiation in the ultra-violet is harmful and that under favorable conditions it will cause cataract in the course of several years. Excess of visible or luminous radiation produces discomfort to the eye, and if the eye is continuously exposed to too great illumination, injury results. Intra-red radiation when not accompanied by excess of ultra-violet or luminous radiation is not generally regarded as harmful. It must, however, be recognized that such radiation is uncomfortable to the workers in low temperature light sources such as glass and steel furnaces. Anything that causes continued discomfort to the eye in the course of years must result in permanent damage. In this connection, it is interesting to note that the use of ordinary clear spectacles reduces the discomfort from such light sources.

As aids to vision, monochromatic light sources have been found to give the greatest possible visual actuity. Such monochromatic light may be the mercury arc and a suitable glass; or the spectrum of white light shortened by filtering through colored glass. The use of "noglare" and orange glass reduces the length of the spectrum to about one-half and one-fourth respectively. It appears, however, that the increase in visual acuity is accompanied by a corresponding increase in eye fatigue and, for visual comfort, the complete spectrum is most desirable. This seems reasonable because the eyes of the human race were developed in an illumination of natural daylight.

For correct color rendering, that is, the same as obtained by natural daylight, the light must have been the same distribution of energy as natural daylight and must appear the same color. Such artificial lights are the Moore-light, the arc light, filtered through a checker board made of colored glasses, or the light from a tungsten lamp filtered through suitable dyed gelatines or colored glasses. Practical glass filters have been made which transmit approximately 15 per cent of the light from the gas-filled tungsten lamp operating at 2850° absolute. This low transmission is an objection from the standpoint of the user, but is not prohibitive considering the high original efficiency of gas-filled lamps.

The Thermo-Electric Properties of Fused Metals. C. R. DARLING and A. W. GRACE. (*Proceedings of the Physical Society of London, vol.* xxix, Part I, p. 82, December 15, 1916.)—In measuring high temperatures by the thermo-electric method, it has hitherto been customary to regard the melting point of either member of the couple of the extreme temperature capable of being measured. As pyrometers of this type are now constructed, the fusion of either metal causes a break in the circuit, and hence for temperatures exceeding 1000° C., it has been found necessary to use junctions of

platinum and an alloy of platinum and rhodium. If, however, a pyrometer could be arranged so that the fusion of either member of the junction would not destroy the circuit, it might be possible to use cheap metals over very high ranges of temperatures, provided that the boiling points were not too nearly approached. The boiling points of metals have been investigated by Greenwood, who has shown that the values for common metals frequently exceed 2000° C.; tin, for example, boiling at 2270°, copper at 2310°, and iron at 2450°. It would, therefore, appear feasible, in a specially designed pyrometer, to measure temperature as high as 1500°, and probably higher, by using common metals in the molten condition, provided their thermo-electric properties were suitable. Further, in the case of bismuth, which boils at 1420°, the high E.M.F. developed when this metal is joined to iron, copper, etc., suggests that possibility of delicate measurements over a range from 0° to 800° or 1000°, again assuming that the thermo-electric properties after fusion are satisfactory.

With these objects in view, an investigation was commenced by the first named author about three years ago, but owing to the abnormal conditions prevailing, progress has been very slow. As a preliminary, it was necessary to determine whether any notable change in thermo-electric properties was caused by fusion, and the results arrived at in this connection were given at the meeting of the Society held on June 30, 1916. It was then shown that in the cases of lead, tin, zinc and cadmium, using a variety of metals as second members of the junctions, that no perceptible break occurred in the continuity of curves obtained by plotting E.M.F. against temperature, either at fusion or at any subsequent stage up to 700° C. With bismuth, however, several cases were noted in which the E.M.F. remained nearly constant after fusion over a wide range of temperature, reproducing the phenomenon of thermo-electric "halt" observed by Barrett with a junction of iron and an alloy of iron, nickel and manganese containing 1.2 per cent. of carbon. This property of molten bismuth has since been more carefully examined, and also the behavior of molten bismuth in cases where this halt is not obtained. It is evident from the results that molten bismuth cannot be utilized for the measurement of temperatures. Its thermo-electric properties after fusion are different from those of tin, lead, zinc and cadmium, all of which show no marked discontinuity as the result of fusion. Preliminary experiments with antimony suggest a similarity to bismuth in this respect.

Mistakes Regarding Focal Lengths and Lens Stops. F. C. LAMBERT. (*The Photographic Journal of America*, vol. liv, No. 1, p. 22, January, 1917.)—Two questions which constantly arise among users of photographic apparatus are how to measure the focal length of a lens and how to measure the f/–values of the stops. For very

rough-and-ready purposes it suffices to focus the lens on any distant object, measure the distance from the ground glass, on image plane, to the stop, and call this the focal length. Also if this value of the focal length be divided by the diameter of the stop, we get the f/–value of the stop. This is only correct when, as happens somewhat rarely, the posterior nodal point, or Ganss plane, happens to coincide with the stop. The nodal point may be found by trial. The method employed is to support the lens in a horizontal position upon a vertical axis. A sharp wire nail driven into a cork will answer for the vertical axis and the lens may be held against it in place by hand. Having brought a screen opposite the lens in such a position that a distant object is accurately focused upon it, the pivot is adjusted normally to the screen until any slight twist of the lens in the horizontal plane about the pivot point will produce no motion of the image on the screen. When this condition is secured, the distance of the pivot point from the screen is the true back focal point. By repeating the process with the lens in reversed position, the front focal point may be found. These points may be marked upon the tube for future reference.

The true f/–value of a stop is found by dividing the focal length by the diameter of the cylinder or pencil of light *entering the lens*. In the case of a single lens with a stop in *front* of the lens, the diameter of the stop measures the entrant pencil. But where the stop is behind the lens, the diameter of the stop is smaller than the entrant cylinder. Hence in this case, if we divide the diameter of the stop into the focal length, we should get the stop number too large. The true lens-face value of the stop may be measured by standing the lens vertically and placing across the diameter a card held on edge so that a series of long graduations drawn upon it will be substantially parallel to the axis of the lens. On looking down along the lines, one of which is arranged to agree precisely with one end of the apparent diameter of the stop, the distance to the opposite diameter can be read from the scale.

French and German Light Field Artillery. A. DUMAS. (*Le Genie Civil*, vol. lxv, No. 21, September 19, 1914.)—(Descriptions of later date of this equipment have appeared, but none available appears more complete or authoritative than the one from which this abstract is made.—ED.) The French 75 millimeter rapid fire field gun, so frequently mentioned in war despatches, is not in its essential features a very recent production. It dates from 1897 when it was adopted to replace a slow firing arm of 90 millimeters calibre of a well-known type. It is better adapted to modern requirements and has a maximum rate of fire of 20 shots per minute. This rate of fire is attained, not by any one revolutionary feature of design but by the refinement of methods of operation now common in various forms to all light artillery. Prominent among these are the use of fixed (car-

tridge) ammunition, a long-recoil mount, and a quick-acting breech mechanism.

The calibre of 75 millimeters was adopted with the object of reducing the weight as far as practicable. Its 33-calibre length of barrel is somewhat greater than is generally employed in a field gun. The barrel is, as usual, a steel forging of suitable quality reinforced with a jacket. Departing from the common practice of hot shrinking, the jacket is forced in place cold, a method of assembling which avoids the molecular changes consequent upon hot shrinkage. The breech block, although screwed in place, is not of the interrupted screw system now extensively employed in guns of all calibres. In its elemental features the breech is closed by a threaded cylinder, whose axis is parallel to the axis of the bore somewhat greater in diameter than twice the bore. The breech housing into which this is fitted is eccentric with the bore so that an orifice in the block at the same eccentricity with the axis of the block is diametrically opposite the bore when the block is screwed home. In that position the bore is covered by the base of the block. A rotation of 180 degrees brings the opening in the block in line with the bore and the breech is open for loading.

Perhaps the most serious obstacle to securing rapid fire in the former type of field gun lay in the undoing of the pointer's work by the recoil; after every shot the gun had to be repointed. In modern field guns the carriage is anchored to the ground as firmly as possible and does not move. A pair of sliding ways controlled in position by the elevating and training gear but otherwise rigidly attached to the carriage is provided. The recoil takes place by the backward movement of the gun along these ways. This backward motion is restrained, partly by a spring but mainly by a hydraulic buffer which consumes most of the recoil energy, while that part stored in the spring serves to push the gun forward into firing position. These retraction springs, usually helical springs of steel, have proved a troublesome feature, and the greatest care in their manufacture has been essential for their successful performance. In the "seventy-fives" steel springs are replaced by compressed air. As the gun recoils the buffer fluid forces a free piston into an air-filled closed cylinder. The air so compressed pushes the gun into firing position, by its reversed action upon the piston after the recoil energy is consumed, and constitutes an ideal spring if leakage troubles can be overcome. The successful use of this device is one of the unique features of the gun. The recoil travel is 1.20 meters. Bearing in mind that in operation the barrel of the gun moves back and forth in a stationary slide, the sighting mechanism, which is attached to this member, is undisturbed.

The German field gun is of a model originally issued in 1896 and modified in 1906. In its modernized form it has an equipment practically similar to the French field piece, the difference being of design and dimensions. The barrel is 77 millimeters calibre and its length is

27.3 calibres. The breech is closed by a block, arranged to slide transversely to the bore, a method which is typical of the system in general use in German artillery. The recoil is absorbed by a hydraulic buffer in which a helical spring is used to return the gun to firing position.

A tabular comparison of the leading dimensions and performance of the two guns shows clearly to what extent they differ.

		French 75	German 77
Length of piece	meters	2.475	2.400
Maximum range	kilom.	6.500	5.300
Weight of projectile	kilogr.	7.200	6.850
Weight of charge	kilogr.	0.700	0.570
Weight per unit of section	kilogr.	163.	147.
Initial velocity	meters	529.	465.
Velocity at 1000 meters	meters	413.	369.
Velocity at 2000 meters	meters	334.	310.
Velocity at 3000 meters	meters	290.	275.
Muzzle energy	kg./m.	103.5	75.
Energy at 2000 meters	kg./m.	40.9	33.6
Number and weight of shrapnel balls		300 @ 12 gr.	200 @ 10 gr.
Danger zone for height of 1 meter:			
At 1000 meters	meters	41.	31.
At 2000 meters	meters	15.	12.
At 3000 meters	meters	7.6	6.5
Thickness of shield	millimeters	3.	5.
Weight of piece in action	kilogr.	1100.	950.
Weight of piece limber equipped	kilogr.	1950.	1850.

The Perception of Light of Short Duration. A. BONTARIC. (*Revue Scientifique*, vol. 54, No. 23, p. 720, November 25, December 2-9, 1916.)—Since 1911, extensive investigations of high academic interest and great practical value have been carried on by Blondel and Rey on the perception of a flash at the limit of visibility. The object of these researches was to determine the minimum illumination visible when the illumination is maintained during a variable but very brief period. According to previous researches by Bloch, the luminous impressions produced upon the retina by sources of varying intensities are equal when the sources act during periods inversely proportional to the illumination which they produce. According to this law, two sources are equivalent for the production of a minimum sensation when the product of illumination and its duration remains constant.

Blondel and Rey have shown that this law is applicable to intense and very brief sources. In the great majority of cases it is not in agreement with experiment. From a series of readings by a considerable number of subjects, they have found that the equation

$$Et = A + Bt$$

expresses the law between visible illumination and its duration, where E is the illumination, t, the time, and A and B constants. If t is infinite, that is if the illumination is steady, $A = E_o$, the least perceptible steady light. From a plot of the observations $A = 0.21\ E_o$ and

$$(E-E_o)\ t = 0.21\ E_o$$

From the practical point of view these results are of particular value in their application to lighthouse and other light projecting apparatus.

Development of the Optical Glass Industry. ANON. (*British Journal of Photography*, vol. lxii, No. 2949, p. 607. November 10, 1916.)—Though photography is not responsible for the introduction of optical glass, it affected its manufacture to a considerable extent, as it imposed special conditions that otherwise would not have been considered. The all-important distinction between optical and other ordinary glass is not merely one of composition, but one of quality as well; it must be homogeneous and free of striæ. The method of producing such glass was discovered about 1807 and its successful manufacture accomplished about 1814, Guinand, a Swiss, being credited with the first conception of the method, and Fraunhofer, a Bavarian, with the development of its application. Through Guinand's sons the secret of the method of manufacture found its way into France and eventually into England. The manufacture of optical glass in the former country began to be important about 1829 and in England (by Chance Brothers) about 1848, and those two countries rapidly obtained the lead in the industry.

Prior to the discovery of the right method of making optical glass, opticians had to be content with merely selecting the best samples of glass they could find from material made in the ordinary fashion, in consequence of which only small lenses could be produced. The discovery of the right method of manufacture enabled Fraunhofer to produce lenses of nearly 10 inches in diameter, whereas the further improvements made by Chance Brothers, in England, led to the production of 29-inch lenses in 1855. Just about the time when Fraunhofer succeeded in mastering the mechanical details of optical glass-making, he discovered a method of testing the optical qualities of glasses of different composition, and of expressing these qualities in figures. In 1804 Wollaston discovered the black lines in the color spectrum, which were afterward called Fraunhofer-lines. In 1814 Fraunhofer applied the spectroscopic method to the testing of the optical qualities of glass and promptly applied the results to the production and examination of new varieties. Up to that time only two varieties of glass were in use for optical purposes, crown and flint. With regard to the discovery that a combination of crown and flint lenses could be achromatic, Dolland is generally assumed to have been the originator in 1757, though Chester Morse Hall produced the first achromatic

telescope in 1733, and there is evidence that the credit properly belongs to Hall. Out of this discovery eventually grew a demand for more varieties of glass, for with the simple crown and flint only a limited correction was possible. At first only the visible rays needed correction, and with the advent of photography the invisible rays required correction to secure a sharp photographic result. Color work has made further demands and practically requires that the lens be corrected for the whole of the visible spectrum. Fraunhofer having found means to test glass, set about this task, but his early death stopped further progress.

The deficiencies of flint and crown achromatic combinations were recognized, and numerous attempts were made to produce suitable glasses, but the difficulties and expense of the work handicapped and discouraged all experimenters on a small scale and little real progress was made. When Abbe and Schott, however, showed their willingness to undertake the work, at Jena, a liberal government enabled them to carry the matter through, and, as the result of a vast number of trials and tests, they produced glasses well adapted to the manufacture of achromatized lenses. The example of Schott was followed closely by Chance in England and Mantois in Paris, and at the present day optical glasses of great variety are obtainable. It should be noted that Fraunhofer should fairly receive the lion's share of credit due to those who have helped to develop optical glass. His early demise, only, in all probability prevented him from completing the results later achieved by others with virtually the same materials as were used by him in his early work.

The Cinematograph for Ordinary Portraiture. A. LOCKETT. (*The British Journal of Photography*, vol. lxiii, No. 2953, December 8, 1916.)—Frequenters of cinematograph theatres can hardly fail to notice the excellent examples of portraiture which occur in the film pictures. This is all the more remarkable, considering the enormous enlargement they have undergone on the screen and the impossibility of retouching. In spite of these disadvantages, the posing, lighting, modeling and expression—but particularly the latter—are often of a kind which could scarcely be surpassed by all the skill of the retoucher and finisher. It might be well worth the photographer's while to try a cinematograph camera occasionally for portraiture, if only for the added naturalness and vivacity gained by the sitter's lack of constraint, and the reassuring knowledge of absolute freedom of movement. There is, of course, no need to expose a large quantity of film. It is only necessary to turn the handle for a second or two, whenever a pleasing pose or expression is assumed, watching the sitter's movements in the finder. The resulting film negatives are critically examined, to select, say, the half-dozen best, and from these, enlargements or enlarged negatives can be made.

The cost of several feet of negative film compares favorably with

that of the same number of half-plates. One foot of film, taking one second to expose and yielding sixteen pictures, costs about 2½d., while half-plates are at present 4 shillings per dozen. The time lost in elaborate posing, focussing, changing of slides, etc., is saved, and so also is retouching, except in the case of enlarged negatives where it is optional. The useful limit of enlargement is usually to post-card or cabinet size, the later being, roughly speaking, an enlargement of six diameters.

Secret Wireless Receiving. ANON. (*Electrical World*, vol. 68, No. 25, December 16, 1916.)—The idea of using small concealed aerials, whether of the ordinary open or closed magnetic loop types with extremely sensitive modern radio receiving instruments, seems to have occurred to a number of experimenters. In the laboratories of the U. S. Bureau of Standards such combinations have been developed to the extent that the reception of signals is possible from the powerful continuous-wave transmitters in Germany, 4000 miles away. When the loop aerial is used, it becomes feasible to determine the direction from which the signals are coming; with two loops at right angles, and a variable phase receiving transformer, rapid measurements of bearing can be made. At Union College there has also been some work done in the development of these small receiving aerials. Messages from stations all over the United States, according to report, have been received, and there is said to be less difficulty from atmospheric and other interference than when the usual tall aerial is used. Manifestly, if small wire arrangements located within doors can be used with equal effectiveness in place of the tall structures usually resorted to, considerable economies of installation and maintenance should result.

So far as has been disclosed, there is no radical change in the indoor aerials now under test as compared with those tried in the past years. The amount of energy abstracted from the passing electromagnetic wave is small when considered in its relation to the power which would be developed by the same wave in a high antenna-wire. In spite of its feebleness, however, the received impulse can now be utilized to produce an indication, because of the availability of recently developed vacuum-tube amplifiers. Signal effects so weak as to be entirely lost by the radio receivers of five years ago can now be built up to sufficient strength for easy telegraphing.

Vacuum relays are particularly suitable for use in conjunction with small receiving aerials, for the tiny absorbing systems are not subjected to the severe atmospheric impulses which play havoc with amplifying receivers as ordinarily used. Thus it is possible to take advantage of high powers of magnification, and to secure signals of commercial intensity without too much trouble from stray interference. Directive receiving tends to minimize the harmful effects of vagrant signals, and to some degree those of atmospherics. As a

whole, the indoor antenna appears to be distinctly practical; and the opportunities it offers for concealment should make its use of marked military value.

New Chemical Industries in Southern California. A. W. KINNEY. (*Los Angeles Times*, December 17, 1916.)—The year 1916 has been the most notable year in the history of Southern California in the amount invested in chemical manufacturing enterprises and in the number of new products exploited. Millions of dollars have been expended in modern plants and more than twenty new products have been developed, samples of which are on display at the industrial bureau of the Chamber of Commerce. In view of the authoritative statement that in California there exists a wider diversity of the crude chemical materials of nature than in any similar area of the world, it is not strange that this section is playing a prominent part in the exploitation of new materials and is doing its full share in the upbuilding of American chemical industry.

During the year $1,500,000 has been invested in a powder plant at Chula Vista, below San Diego City proper. At the harbor district of Los Angeles five good-sized kelp products concerns have begun operations during the present year. After considerable investigation the Department of Agriculture has decided to locate at Summerland, Santa Barbara County, an experimental kelp products plant which will have a capacity of 200 tons of kelp per day. This institution will cost approximately $175,000, and will give the potash industry a thorough tryout. Two costly refineries have been erected at Searles Lake, San Bernardino County, and at Los Angeles Harbor. Potassium chloride is now being shipped from the Searles Lake plant. Other probable products from this and the harbor plant are caustic potash, permanganate of potash, bicarbonate of potash, borax, sodium carbonate, chloride and sulphate. Another large chemical enterprise is that the Solvay Process Company, which will handle similar products. Other sources of potash exploited during the year have been a Portland cement plant and the various beet-sugar factories.

At San Diego a plant has commenced operations devoted to the production of orcein dyes, using as raw material the orchilla weed, a moss found growing in vast quantities along the western coast of Lower California. It is claimed that these dyes can be produced cheaper than the imported article and are equal, if not superior, to it. Another company will engage in the manufacture of aniline dyes, utilizing the by-products of the local refineries and gas plants. Among other products now available are citric acid from cull lemons, strontium nitrate, chlorine, hydrated lime, and molybdenum and tungsten compounds. This has indeed been a most remarkable year in chemical development, and adequate research work should result in converting the great variety of raw material available into commodities that will eventually yield very large returns to the region.

The Manufacture of Linoleum. E. S. WIARD. (*Metallurgical and Chemical Engineering*, vol. xv, No. 12, December 15, 1916.)—The process of making linoleum, the familiar water-proof floor covering, was invented by Frederick Walton in England in 1860 and the product was first brought out under the name Kamptulicon, but later received the name Linoleum. The foundation of linoleum is jute burlap. This is coated with the very best grade of finely ground cork bonded with a water-proof material. For the bonding material, linseed or other drying oils are used, these being oils which on exposure to the air will absorb sufficient oxygen to form a solid resinous mass. The linseed oil must be of good quality. The oil is first boiled, as in paint making, and the process of drying is facilitated by adding a small quantity of oxide of lead. From the boiling tanks the oil passes to pieces of light cotton fabric, known as scrim, which hang vertically from iron bars. The oil is poured over the scrim and what adheres to the surface at a temperature of about 100° F. becomes hardened. The operation is repeated from time to time until there is a coating on the scrim of sufficient thickness, when it is cut down and ground between rollers. The usual thickness of the skin on the scrim is one-half inch. The ground oil is then mixed with resin and kauri gum until the whole mass is homogeneous and forms the bonding cement.

The cement and cork are then mixed together, and if the linoleum is to be plain, the coloring matter is added at this stage. The mixture is then rolled into the jute backing, there being two cylinders to effect this operation and to secure evenness of the layer. The printing of the design is done mechanically by rising and falling color blocks. The movement of the linoleum under the printing blocks is continuous. In the manufacture of inlaid linoleum the mixture of cement and cork is compressed into sheets of different colors which are afterwards cut up into the components of the design and are affixed to the burlap by pressure. In another process the linoleum mixture in the form of a powder is dropped upon the jute in a way to form the design and is then subjected to heavy pressure to fix it and secure a permanent contact with the backing.

Storage of Energy. G. P. PEARCE. (*Machinery* (N. Y.), vol. 23, No. 3, November, 1916.)—In physical problems, the storage and release of energy plays a most important part and the success or failure of many a mechanical device is governed by the space or weight entailed in providing an adequate supply of energy for its operation and by the degree of complication of the apparatus employed for its control. The methods available may be classified into four general divisions. (1) Those employing the elasticity of materials; (2) those employing chemical reactions to generate heat or electricity; (3) those employing kinetic energy, and (4) those operated by the action of gravity.

Where relatively small amounts of energy are required, springs

in various forms have proved simple and effective for the purpose, as in time-pieces and small mechanisms for intermittent use. The amount of energy that can be stored per pound varies with the type of spring. The "screen door" torsion spring will absorb 46 foot-pounds of energy, while the helical spring will store 88 foot-pounds. Of late years large flat spiral (clock) springs have been successfully employed in automobile "self-starters." For less important work rubber has given good results. Years before Professor Langley made his flying machine, a Frenchman made simple toys, which were driven by twisted elastic bands, that would fly 50 feet or more. These simple toys could fly because it is possible to store considerable energy in rubber; in fact, it is superior to the finest tempered steel spring in this respect, for almost 3000 foot-pounds per pound can be absorbed and delivered.

Ordinary air when highly compressed, say around 2000 pounds per square inch, is capable of delivering 50,000 foot-pounds per pound. Steam is even better, and will deliver 240,000 foot-pounds when expanded from 250 down to 2 pounds per square inch absolute. These figures are, however, not comparable with those for steel and rubber when the weight of the containing and transmitting apparatus is considered.

The flywheel is generally looked upon as an ideal device for the storage of power, but a cast-iron wheel reaches its limit at about 640 foot-pounds per pound. A steel flywheel gives better results and will yield about 3200 foot-pounds. The energy of ordinary flywheels sinks into insignificance, though, when compared with that stored in the rim of a De Laval steam turbine disc where it may reach 31,000 foot-pounds. The most efficient electric storage batteries cannot equal this, as they reach their limit at approximately 22,000 to 30,000 foot-pounds per pound and many commercial batteries on the market do not exceed 3200 foot-pounds.

Power Loss in Screw Propellers Due to Rough Surface. ANON. (*Engineering News*, vol. 76, No. 25, December 21, 1916.)—Experiments described in a paper by Naval Constructor William McEntee, U. S. N., at the recent annual meeting of the Society of Naval Architects and Marine Engineers indicate that a great saving of power is effected when ship propellers are made of some non-corrodible metal like bronze and are carefully machined and polished, as compared with the common practice of using propeller castings as they come from the foundry. It is likely that these experiments teach a valuable lesson, also, to the designers and builders of centrifugal pumps. The skin friction of a rapidly moving impeller in a centrifugal pump must be very great, especially in pumps working at high heads; and it seems all but certain that this skin friction must be greatly increased if the impeller is a rough casting.

Usually screw propellers used on naval vessels are carefully fin-

ished by machining the rear surface of the blade to a true helicoidal surface and finishing by hand the front face so that it will be perfectly smooth. The propellers of merchant vessels, however, generally have blades of cast iron or cast steel and are given no finish whatever, except trimming off the rough places with chisel or file. In addition, as is well known, iron and steel propellers often suffer by pitting, so that they present an extremely rough surface to the water.

With the object of determining the relative efficiency of a smooth finished propeller and a propeller left with the rough surfaces of the original casting, four propellers, 16 inches in diameter, were tested at a uniform speed of 5 knots. Two of the propellers were of bronze, one of cast iron and one of cast steel. One of the bronze propellers was finished perfectly smooth; the others were left as they came from the mold, with only the ordinary cleaning. The test showed that the propellers with a rough surface had a maximum efficiency of about 63 per cent. whereas the polished propeller had an efficiency of about 72 per cent. Another test was made to determine the effect of a still rougher surface, such as exists on a propeller that becomes badly pitted or on which barnacles and other sea growths accumulate, by varnishing the polished bronze propeller and applying to the sticky varnish a layer of granulated cork, such as is used for cork paint in ship work. The efficiency of the artificially roughened propeller which had been about 72 per cent. in its polished condition was reduced to 36 per cent.

A Rapid Process for Determining the Acidity of Corn. (*U. S. Department of Agriculture.* Circular 68.)—The test to determine the acidity of corn, which previously required 16 to 18 hours, can be made in less than one hour by the use of improved apparatus developed by H. J. Besly and G. H. Baston of the office of Grain Standardization, Bureau of Plant Industry. Under the new method an electric mechanism, similar to those seen on soda fountains, is used to mix finely ground corn and alcohol. Thirty minutes of mixing, it is found, will extract from the corn an amount of acid-reacting substances comparable to the amount extracted through digestion in 86 per cent. alcohol at room temperature for 18 hours.

The methods for making acidity determinations of corn with this apparatus are described in detail in circular 68, Office of the Secretary, recently published by the U. S. Department of Agriculture.

French National Laboratory of Physics and Mechanics. ANON. (*Metallurgical and Chemical Engineering,* vol. xvi, No. 4, p. 186, February 15, 1917.)—The Academie des Sciences, according to the *Genie Civil,* has resolved to establish a national physical and mechanical laboratory for the purpose of scientific research directed toward industrial uses. The laboratory will be controlled by a council,

of which half the members will be nominated by the Academy, one-fourth by the State Department, and the remainder by the chief industrial associations. The executive control will be in the hands of a small technical committee. Existing laboratories engaged in similar work will be affiliated to the National Laboratory, and will work in close relationship to the latter. Substantial funds will have to be provided for the working expenses of the laboratory and for the assistance of the affiliated institutions.

Manganese Steel Castings. W. S. McKEE. (*The Iron Trade Review*, vol. lx, No. 7, p. 413, February 15, 1917.)—Manganese steel was developed originally in England, largely through the efforts of Sir Robert Hadfield. It has been manufactured on a commercial scale for nearly 26 years. The first manganese steel castings made in the United States were turned out in 1892. Originally it was considered impossible to make manganese steel castings successfully weighing over a few hundred pounds, but at the present time large rolling-mill pinions, crusher heads, and similar castings weighing up to 30,000 pounds each are being produced regularly, and it does not appear that the limit of weight has been reached by a considerable margin.

As manufactured at present, manganese steel is similar in analysis to ordinary converter metal, except that it is high in carbon and unusually high in manganese. In ordinary commercial castings the proportions of the latter metal range from 11 to 13½ per cent. This combination of constituents gives the finished castings certain distinctive physical properties. Heat treatment is a very essential part of the process. The necessity for heat treatment limits the thickness of section which it is possible to cast successfully. Originally the castings were made with comparatively thin sections, but researches during the past few years have made it possible to increase the thickness of section, so that at present castings with walls up to 5½ inches in thickness are handled satisfactorily. Manganese steel made by Robert W. Hunt & Co., Chicago, has an elastic limit of 53,400 pounds, tensile strength of 108,400 pounds per square inch, an elongation of 33.7 per cent. in 2 inches, and a reduction in area of 38.6 per cent. This steel does not owe its wear-resisting qualities to its hardness. When subjected to the Brinell test, it shows an average hardness number of 200. The electrical resistance of manganese steel is about 3.4 times that of ordinary Bessemer steel. It is non-magnetic, and advantage is taken of this property in the use of this material for shields or bottom plates of lifting magnets.

If the castings require finishing, special equipment is necessary. Ordinary machining methods are unsuccessful, and grinding must be employed. Holes more than ¼ inch in diameter are cored and ground to size. When it is necessary to drill smaller holes or to cut threads, soft steel or wrought-iron inserts are set in the molds at desired points like chaplets and the metal is cast around them.

Effect of Centrifugal Force on Colloidal Solutions. E. E. AYRES, JR. (*Metallurgical and Chemical Engineering*, vol. xvi, No. 4, p. 190, February 15, 1917.)—Particles of a uniform size suspended in a liquid medium will settle by gravity when the product of their masses in grammes by the constant 3×10^{16} is as large as 10. When the product is less than 10, a partial subsidence will occur until an equilibrium is established. The only considerable force opposing complete subsidence in this case is osmotic pressure. By the use of a law of distribution which takes into account the opposing forces, it is possible to compute the concentration at any level when the system is at equilibrium. When the conditions are such that a particle will not settle completely by gravity, it is possible to cause complete subsidence by the application of centrifugal force when the product of the mass in grammes, the force in dynes, and the constant 3×10^{16} is greater than 10. Here, again, a partial subsidence with the establishment of an equilibrium will occur when the product is less than 10. The time required to establish this equilibrium can be computed from a modification of Stokes's law for velocity.

The highest commercial centrifugal force, 40,000 times gravity, can completely remove particles as small as the lower limit of ultramicroscopic observation, but such a separation will require 33 hours when the liquid medium is water. For less viscous media the time will be shortened. Smaller particles can never be separated by this force. Particles just too small to be retained by a fine porcelain filter can be removed in a few seconds. Gases at different densities cannot be completely separated by any force less than about 100,000,000 times gravity. The same applies to true solutions. But gases should be partially separated by a much lower force within a reasonable time, whereas solutions in liquid media would require several weeks.

Corona and Rectification in Hydrogen. J. W. DAVIS and C. S. BREESE. (*Proceedings of the American Institute of Electrical Engineers*, vol. xxxvi, No. 2, p. 143, February, 1917.)—When a sufficiently high potential difference is impressed between two parallel wires, or a wire and concentric cylinder, separated by air or some other gas, this gas, which for low potential gradients is a very good insulator, breaks down and becomes a partial conductor. The phenomena connected with this character of conduction through gases are known collectively by the name corona. The failure of the gaseous dielectric separating the metallic conductors is made evident by a flow of current from one conductor to the other, by a power loss, and, in practically all cases, by the appearance of light at either one or both of the conductor surfaces. In some cases light appears in the intervening space. Since the present theories as to the mechanism of corona formation do not satisfactorily account for all of the observed phenomena, it was decided to carry out further investigations in the

hope that, when enough data were accumulated, some theory based on fundamental principles explaining the observed phenomena might be evolved.

Both direct and alternating electromotive forces were used, and the characteristic behavior of the corona was given by means of curves, photographs, and oscillograms. The corona discharge in hydrogen was found to differ from that in air in the following particulars: The discharge from a negative wire was found to differ widely from a positive wire in the magnitude of the voltage necessary to start the discharge in the shape of a volt-ampère characteristic and also in the stability of the discharge. Corona in hydrogen between concentric cylinders is shown to be a practicable method for rectifying high potential alternating currents.

Internal Temperature of A. C. Generators. R. KELLY. (*Proceedings of the American Institute of Electrical Engineers,* vol. xxxvi, No. 2, p. 119, February, 1917.)—The results of tests of a number of typical large A. C. generators show that there is a wide divergence between internal and surface temperatures in A. C. generator stators, the internal temperature being measured by a thermocouple placed between armature coils in the same slot and in the centre of the core. The difference between these measured internal temperatures and the corresponding surface temperatures in the tests varies from 0° to 35.5° C. This wide divergence is explained by the aid of the tests and of calculations. A method of calculation for internal temperatures is given which is based on simple heat laws and on data obtained from many tests. By means of the tests and of parallel calculations, the effect on the internal temperature of changes of frequency, core length, thickness and quality of insulation, armature current densities and core densities is explained. The capacity of the end windings to dissipate heat is also discussed. In conclusion, it is stated that, although the wide divergence between surface and internal temperatures of different classes is regular and can be justified, yet it is plain that there is no one average figure that can be used for that difference for all classes of A. C. generators.

Casting High-speed Steel Tools to Shape. ANON. (*American Machinist,* vol. xxxxvi, No. 7, p. 285, February 15, 1917.)—It is a commonly-accepted idea that metal-cutting tools—lathe or planer tools, milling cutters, and the like—have to be made from bar stock or special forgings. To think that tools of this class can be made in practically the same manner as common castings is a decided departure from established precepts, especially when these tools are of high-speed steel. However, Anton Boerder, some time ago, invented a process by which high-speed metal-cutting tools of all kinds can be cast to shape, leaving from one-sixteenth to one-eighth of an inch for finishing. Tools of this kind are now being cast by the High-speed Tools Corporation, Toledo, Ohio. From reliable sources it is re-

ported that these tools compare favorably in edge-holding qualities with forged or bar machined stock, and that it may be forged into various shapes when necessary. The large saving in time and material in finish-machining such tools is at once apparent to any practical shopman. This company also casts bars and billets for various purposes.

The company does not machine the tools, but supplies them to shops as ordered, just enough extra metal being allowed to clean up well and give a good edge where needed. The tools are cast from patterns exactly as if pouring from cast iron, and, after being cleaned and carefully annealed, are ready for delivery. The heat treatment recommended is as follows: Bring the steel slowly to 650° F., raise to 1200, then raise quickly to 2250 and quench in fish oil until cool. If a gas furnace is used, supply more gas than air in order to prevent the steel from acquiring a soft cutting edge.

Oscillating-current Circuits by the Method of Generalized Angular Velocities. V. BUSH. (*Proceedings of the American Institute of Electrical Engineers,* vol. xxxvi, No. 2, p. 189, February, 1917.)—The oscillating-current circuit differs from the alternating-current circuit in that the sinusoids involved are damped. In the same way that alternating-current theorems are obtained by generalized direct-current theorems, it is possible to obtain oscillating-current theorems by still further generalization. This involves a generalized angular velocity and a generalized impedance which are complex quantities. Kirchoff's law thus generalized yields a simple method of determining the generalized angular velocities, and thus the frequencies and decrements, of free oscillation.

In an oscillating-current circuit, there being no impressed voltage, the initial voltage present in the circuit must be used in determining the amplitudes of oscillation. This results in the introduction of a "threshold impedance" for use in determining the amplitudes, which is obtained by a single differentiation from the generalized impedance. Further direct-current rules may also be readily generalized for convenient use in the solution of oscillating-current circuits. A simple example is given to show the method of procedure. The discharge of a leaky condenser through a reactor furnishes a second example which better illustrates the convenience of the method for numerical computations. As a third example, the oscillation of a three-section artificial cable under particular terminal conditions is chosen.

Progress in Aërial Navigation. SANTOS-DUMONT. (*Flying,* vol. vi, No. 1, p. 31, February, 1917.)—On the 14th of July, 1903, the author piloted a dirigible at the Longchamps military manœuvres in which 100,000 troops took part. That was the first time aërial navigation was a feature of a military demonstration. At that time it was predicted that aërial warfare would be one of the most important

phases of future military campaigns. The prediction was scoffed at and resented by militarists, who could not see the airships in any light but as a childish toy. The present war, however, has demonstrated that aëronautics has revolutionized warfare; aircraft are now employed in every branch of military service.

Less than a decade ago the author's aëroplane was considered a marvel. In this machine, in which there was place for only one person, a motor of about twenty horsepower was used. At first, flights of only a few metres could be made. Only enough gasoline to fly three-quarters of an hour could be carried, and the longest flight was twelve miles. To-day machines are being made with engines of 1000 horsepower, capable of carrying thirty passengers nearly 1000 miles without landing. A large factory in the United States turns out twelve aëroplanes daily. Among the aëroplanes constructed, there is one capable of flying over 600 miles and carrying thirty persons. An aëroplane of this type, equipped with four motors totalling over 1000 horsepower, has flown in England with eight passengers and 600 gallons of gasoline and other equipment on board at a speed of 75 miles per hour. This machine is built with three planes spreading 133 feet, with a length of 68 feet, and its total weight is over ten tons. The chief problem which confronted aërial navigation—securing an efficient motor—may be considered solved; the aëroplane motor of to-day is more reliable than the automobile motor was ten years ago.

The Sterilization of Beer by Filtration. E. ZAHM. (*Pure Products*, vol. xiii, No. 2, p. 57, February, 1917.)—A liquid is sterile when it has been freed from microörganisms or the microörganisms therein contained have been deprived of the power of reproduction. In the brewery, beer, before it is filled into the containers in which it is marketed, is subjected to filtration through layers of pulp, so that it is in a state of brilliancy. This beer, nevertheless, contains some microörganisms which have not been removed in the filtering process and, at the warmer temperatures which obtain in beer while marketing, multiply and cause disturbances in the stability of the product. To prevent this fermentation, the process of pasteurization has been generally used, whereby the yeast and other microörganisms have been deprived of the power of reproduction. This process, though it prevents further fermentation, produces undesirable changes in the taste and character of the beer, so that it is generally conceded that a pasteurized beer is inferior to the same product before treatment.

In the process of brewing, a hopped wort is subjected to fermentation through the introduction of yeast. With this yeast are introduced enzymes which are formed during the process of fermentation, which are present in the beer when it is filled into the containers. Thus beer is not merely a solution of extract matter, alcohol, and carbonic acid, but contains enzymes which have a beneficial action

on the digestive functions in the human body. The process of pasteurization arrests or destroys the action of these enzymes as well as that of the microörganisms, with the result that the beers so treated have not only altered in taste, but also lack that enzymatic action which is desirable in beer as a food product. It is therefore readily understood that if beer can be brought to a sterile state in the bottle and marketed with its enzymatic power unimpaired, a superior product is assured.

Filtration to sterility produces such results. That liquids can be filtered to sterility has been known for many years, and the process has been generally used in the treatment of serums and other liquids in the laboratory. A filter of the type generally used in breweries, in which the filtering medium consists of layers of fibrous pulp, is not adaptable to sterile filtration. This is not because the interstices of pulp mass are not minute enough to withhold the passage of the microörganisms, but because, under pressure fluctuations, the interstices change in form and size, permitting some of the microörganisms to pass. Both the porcelain and clay tube filters are impracticable because of their limited capacity. The filtering properties of diatomaceous or infusorial earth are far superior to other known substances adaptable to filtration, and were adopted as most satisfactory for the purpose. An apparatus equipped with a battery of 110 cylinders of this material, two inches in diameter and about a foot long, has a capacity of fifty pint bottles per minute.

Formation of Clinkers in Boiler Furnaces. A. A. CARY. (*Electrical World*, vol. lxix, No. 6, p. 267, February 10, 1917.)—During many years' experience in designing, testing, improving, and operating furnaces, used for many purposes, no branch of this subject has been found that requires more consideration than the troublesome formation of clinkers in the furnace and the formation and growth of clinkers on furnace linings. In a great majority of cases, this trouble can be either greatly reduced or avoided, for clinkers are formed by the fusion of the ash and refuse which remain after the combustion of the coal in the furnace. Ash is really a very useful material in the furnace when it is properly taken care of there; since, with proper thickness of ash covering the top surface of the grate, the burning and warping of the bars are prevented.

Where properly designed shaking bars are used, the thickness of the ash-bed on the top surface of the bars can be easily regulated, and it is very necessary that this be properly accomplished with this type of bar, as most of the shaking grates are designed with thin, delicate edges which are easily burned or warped when brought into contact with a hot fire-bed. It is quite essential that the thickness of the ash-bed should always be reduced before any attempt is made to break up the fire-bed above, otherwise the ash will be thrown up into the bed of fuel and fused into clinker. The shaking grate, improperly used, may be productive of more clinker in the furnace than would

occur with the plain stationary grate in use. The thickness and conditions of the fire-bed have much to do with this grate and clinker trouble, however. The density of the fuel bed is really of more importance than its thickness. A comparatively thin fire-bed that is dense and compact will hold the ash within its hot body, instead of allowing it to precipitate to the grate bars, just as much as a thicker bed when it is more open and porous.

When any fire-bed is more or less solid or compact, the air for its combustion will not pass uniformly throughout its mass, but, on the contrary, this air will search out its easiest paths of passage and flow through the irregularly scattered openings formed by cracks or holes in the fire-bed, and, with the ash held up in this densely-packed bed, the air, rushing through these selected positions, will cause intense combustion to occur at such places, which rapidly fuses the surrounding ash into clinker and at the same time causes the soft, pasty mass to attach itself to a considerable amount of solid combustible fuel. Too thin fires carried on the grates should be avoided, especially with shaking grates, as every fire-bed should be of sufficient depth of ash to be carried on the bars to protect them from the intense heat of the burning fuel above them. Excepting these very thin fire-beds, it may be said that the intensity of draft required to operate a furnace is, generally speaking, a measure of its clinker-making properties, which is another way of saying that the intensity of the draft required is a measure of the density of the fire-bed.

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